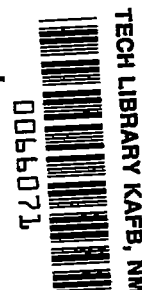# NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 3201

DIRECTIONAL STABILITY CHARACTERISTICS OF TWO

TYPES OF TANDEM HELICOPTER FUSELAGE MODELS

By James L. Williams

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Langley Field, Va.

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The definition of C_D appearing in figure 20 was inadvertently omitted from the "Symbols", and the definition of l on page 3 requires clarification. Therefore, the list of "Symbols" (page 3) should be corrected to include the following information:

Change definition of l in line 11 to read as follows:

l distance between rotor hub centers (4.23 ft for nonover-lap model, and 2.84 ft for overlap model)

Add to the list the following symbols and definitions:

C_D drag coefficient, $D/q(2S_d)$

D drag, lb

$2S_d$ total rotor disk area (26.39 sq ft for nonoverlap model and 28.2 sq ft for overlap model)

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SUMMARY

A low-speed investigation was made in the Langley stability tunnel to determine and improve, if possible, the directional stability characteristics of two tandem helicopter fuselages, one representing a helicopter with overlapping rotors (overlap-type fuselage) and the other a helicopter with nonoverlapping rotors (nonoverlap-type fuselage).

The overlap-type fuselage model was found to be directionally unstable at angles of attack of $10°$, $-10°$, and $-20°$ for angles of sideslip to $\pm6°$ or less. This instability was found to result from an insufficient contribution of the original vertical tail (which was approximately 35 percent chord in thickness) to the directional stability. The failure of the original vertical tail to make sufficient contribution to the directional stability was felt to be associated with the separation caused by the adverse pressure gradient over the relatively thick rear portion of the vertical tail and fuselage. Either blunting the trailing edge of the original vertical tail and fuselage of the overlap-type fuselage or substituting a thin tail (which was approximately 4 percent chord in thickness) for the original tail generally resulted in a directionally stable fuselage-tail arrangement.

The nonoverlap-type fuselage model was directionally unstable for positive angles of attack throughout the sideslip range. This instability was found to result from a low vertical-tail effectiveness and a large variation of the fuselage-alone directional-stability parameter C_{n_β} with angle of attack. Both of these factors were found to be associated with the rate of change with sideslip angle of the asymmetric trailing-vortex system that existed on the fuselage. The use of spoilers located around the nose of the fuselage was the only effective means found, without resorting to major design changes, for making the nonoverlap-type fuselage directionally stable.

INTRODUCTION

The results of flight and wind-tunnel tests (refs. 1 to 3) have shown that two tandem helicopter fuselages, one representing a helicopter with overlapping rotors (overlap-type fuselage) and the other a helicopter with nonoverlapping rotors (nonoverlap-type fuselage) are directionally unstable for certain angles of attack and sideslip. The overlap-type helicopter fuselage has a rear pylon faired to form a thick vertical tail and fuselage rear section, and the nonoverlap-type helicopter fuselage has a center section that is considerably below its front and rear ends. The results of reference 2 have indicated that the directional stability characteristics of the overlap-type fuselage can be improved by an increase in pylon (vertical tail) area or by use of split flaps attached to each side of the tail, which of course act to decrease the adverse pressure gradient over the rear of the tail. Reference 4 presents a comparison of the lift-curve slopes of several airfoils with varying degrees of bevel and trailing-edge bluntness. These results show that the lift-curve slope increases as the trailing-edge angle is changed from a beveled to a somewhat blunted shape. The data of references 2 and 4 suggest that the directional instability of this type of fuselage-tail arrangement is attributable at least partially to a low lift effectiveness of the vertical tail that is associated with its large trailing-edge angle and indicate that possibly further improvement in the directional stability can be made by a more complete blunting of the trailing edge of the vertical tail and lower aft portion of the fuselage than was employed in reference 2, wherein the blunting was essentially confined to the pylon.

The results of some exploratory tests on the overlap-type fuselage in the Langley free-flight tunnel have indicated that the location of spoilers around the fuselage nose considerably improved its directional stability by destroying some of the unstable moment of the fuselage. These results indicate that the directional stability characteristics of a wide range of fuselage shapes, including the extreme nonoverlap-type fuselage configuration, can be influenced by the use of spoilers.

The purpose of the present investigation was to study further the directional stability characteristics of these fuselages and to find solutions, if possible, that would give satisfactory stability. To this end, a series of tests of an overlap-type fuselage with various fuselage and pylon modifications and of a nonoverlap-type fuselage with various spoiler arrangements were made in the Langley stability tunnel. These tests consisted of the measurement of aerodynamic forces and moments throughout a range of sideslip and angles of attack, and also a short study of the air flow around the nonoverlap-type fuselage by means of the tuft-grid technique of reference 5.

SYMBOLS AND COEFFICIENTS

The data are presented in the form of standard NACA force and moment coefficients and are referred to the wind system of axes with the origin at the assumed centers of gravity of the fuselages. The positive directions of forces, moments, and angles are shown in figure 1. The symbols and coefficients employed are defined as follows:

A	aspect ratio, b^2/S
b	horizontal-tail span (measured perpendicular to fuselage reference line), ft
c	tail chord, ft
l	distance between rotor hub centers, ft
S	area, sq ft
t	vertical-tail thickness, ft
V	free-stream velocity, ft/sec
q	dynamic pressure, $\frac{1}{2}\rho V^2$, lb/sq ft
ρ	mass density of air, slugs/cu ft
α	angle of attack, deg
β	angle of sideslip, deg
Y	side force, lb
N	yawing moment, ft-lb
L'	rolling moment, ft-lb
C_Y	side-force coefficient, $Y/q2S_d$
C_n	yawing-moment coefficient, $N/q2S_d l$
C_l	rolling-moment coefficient, $L'/q2S_d l$
$C_{n_\beta} = \dfrac{\partial C_n}{\partial \beta}$	

F_1, F_2, F_3 fuselages 1, 2, and 3, respectively (see figs. 2(a) and 4(a))

$T_1, T_2, \ldots T_6$ tails 1, 2, . . . 6, respectively (see figs. 2(c), 2(d), 3, and 4(b))

$\triangle_3 C_Y, \triangle_3 C_n, \triangle_3 C_l$ mutual-interference increments in C_Y, C_n, and C_l; for example, $\triangle_3 C_Y = C_Y{}_{(\text{fuselage with tail})} -$

$C_Y{}_{(\text{fuselage alone})} - C_Y{}_{(\text{tail alone})}$

Subscript:

d   rotor disk

MODELS, APPARATUS, AND TESTS

The basic overlap-type fuselage model (fuselage 1) used in the present investigation was constructed of balsa and was approximately a 1/7-scale model of a current tandem helicopter fuselage which has a rear pylon faired to form a thick vertical tail ($t/c \approx 0.35$; tail 1) and fuselage rear section (see figs. 2(a) and 2(c)). A sketch of the modification made to fuselage 1 to obtain fuselage 2, which had a thinner rear section, is shown in figure 2(a).

A thin vertical tail, tail 2 ($t/c \approx 0.04$), was made of plywood (see fig. 2(c)). Vertical tails with blunt trailing edges (tails 3 and 4) and an end plate (see fig. 2(d)) were made of balsa and plywood, respectively. Photographs of the model with tail 1 ($t/c \approx 0.35$), tail 2 ($t/c \approx 0.04$), and blunt tails 3 and 4 are shown in figure 3. It should be noted that when the blunt tails were used the bluntness was extended to include the lower aft portion of the fuselage. A horizontal tail located near the center of the original vertical tail was tested with the model at -10° angle of attack.

The nonoverlap-type fuselage model (fuselage 3) used in this investigation was constructed of mahogany and was a 1/10-scale model of a current tandem helicopter fuselage. The vertical tails (tail 5 and tail 6), however, were made of plywood. Sketches of the nonoverlap-type fuselage and vertical tails are shown in figures 4(a) and 4(b), respectively.

Several spoiler configurations were tested with the nonoverlap-type fuselage model. The spoilers, which were faired to fit the fuselage contour, were made from 1/16-inch sheet brass and were approximately 0.20 inch wide. Photographs of the nonoverlap-type fuselage with and without spoiler

configurations (spoilers 1, 2, and 3) are shown in figure 5. The dorsal
and ventral portions of spoiler arrangement 3 were about 16 inches long.

The models were mounted rigidly to a single strut support, at
approximately the 0.52 point and 0.50 point of the distance between the
rotor hubs for the overlap- and nonoverlap-type fuselage models, respec-
tively, in the 6-foot-diameter test section of the Langley stability
tunnel. The forces and moments were measured by means of a conventional
six-component balance system.

All force tests for the overlap- and nonoverlap-type fuselages were
made at a dynamic pressure of 39.7 pounds per square foot, which corre-
sponds to a Mach number of about 0.16. The test Reynolds numbers were
4.87×10^6 and 5.50×10^6 for the overlap and nonoverlap fuselages, respec-
tively, based on the overall length of the pertinent fuselage. The angles
of sideslip investigated ranged from about 25° to -25°. The angles of
attack used in tests of the overlap-type fuselage were 10°, -10°, and
-20°, and the angles of attack used in tests of the nonoverlap-type fuse-
lage were 30°, 20°, 10°, 0°, -10°, and -30°. The horizontal tail of the
nonoverlap-type fuselage was set at 9° angle of incidence. The tuft-grid
tests were made at a dynamic pressure of 8 pounds per square foot and a
Reynolds number of 2.47×10^6.

CORRECTIONS

Data for the nonoverlap-type fuselage have been corrected for
support-strut interference. These corrections were, in general, of neg-
ligible magnitude for the nonoverlap-type fuselage; therefore the data
for the overlap-type fuselage were not corrected for support-strut inter-
ference effects. Blockage corrections were computed for both fuselages
and found to be negligible. All tail-alone data have been transferred
to the assumed center-of-gravity location of the pertinent fuselage.

RESULTS AND DISCUSSION

Presentation of Data

The basic data in the form of yawing-moment, side-force, and rolling-
moment coefficients and certain summary plots for the overlap-type fuse-
lage models are presented in figures 6 to 12 and 17, and for the
nonoverlap-type fuselage models in figures 13 to 15 and 17 to 23. Tuft-
grid pictures of the flow behind the nonoverlap fuselage models are pre-
sented in figure 16. Inasmuch as the evaluation of the directional sta-
bility is of primary interest in this report, only the yawing-moment data
will be considered in the discussion that follows.

Directional Stability of Overlap-Type Fuselage

Basic model.- The basic-model data for the overlap-type fuselage are presented in figure 6. These data show that fuselage 1 with tail 1 (F_1T_1) is directionally unstable for $\alpha = 10^\circ$, -10°, and -20° at angles of sideslip to $\pm 6^\circ$ or less. A comparison of the result of summing the coefficients for the fuselage alone and tail alone $(F_1 + T_1)$ with the result for the basic model (F_1T_1) at angles of attack of 10°, -10°, and -20° indicates that the instability of this model is made considerably worse at 10° angle of attack by the aerodynamic interference. This interference at 10° angle of attack probably represents a decreased tail efficiency which results from the fact that the tail is in the region of fuselage influence at this angle of attack.

Effect of vertical-tail modification.- The effect on the directional stability of replacing the thick tail (T_1) of the basic model with a thin tail (T_2) may be seen by comparing the data of figures 6(a) and 7(a). The variation of the yawing-moment coefficient with angle of sideslip for tail 2 alone was larger, in general, than that estimated by theory. This increased yawing-moment coefficient might be attributed to the end-plate effect of a portion of the fuselage tested with this tail. Fuselage 1 with tail 2 (F_1T_2) is directionally stable throughout the sideslip range for $\alpha = 10^\circ$ and -10° but about neutrally stable at small angles of sideslip for $\alpha = -20^\circ$. The sum of the yawing-moment contributions of the fuselage alone and the tail alone $(F_1 + T_2)$ for $\alpha = 10^\circ$ and -20° indicates a destabilizing mutual interference between fuselage and tail (compare $F_1 + T_2$ and F_1T_2). However, for $\alpha = -10^\circ$ the mutual interference between the fuselage and tail is stabilizing (fig. 7(a)).

Several tests were made to determine the effect of blunting the trailing edge of the original vertical tail and lower aft portion of the fuselage (see figs. 2(d) and 3) on the directional stability of the overlap-type fuselage. The results of these tests are presented and compared with the directional stability of the basic configuration in figure 8(a). The addition of a blunt tail (tail 3, tail 4, or tail 3 with end plate) stabilized the fuselage for all angles of attack tested. The blunt trailing edge of the vertical tail appeared to be effective in delaying the movement of the separation point on the vertical tail as the sideslip angle increased, and thereby produced a greater vertical-tail lift-curve slope and an improvement in the stability characteristics of the fuselage-tail combination. Blunt tail 3 had a larger area than tail 4, and therefore made a larger contribution to the directional stability (fig. 8(a)).

Effect of fuselage modification.- Experimental results which show the effect of thinning the rear portion of the basic fuselage to produce fuselage 2 are presented in figures 9 and 10. The fuselage modification

resulted generally in an appreciable reduction in the unstable yawing
moment of the basic fuselage alone (see fig. 9). For all angles of attack
tested, fuselage 2 with tail 2 was directionally stable to a greater
degree than fuselage 1 with tail 2 or, of course, fuselage 1 with tail 1
(see fig. 10(a)).

Comparison between overlap-type-fuselage stability and airplane
stability.- The directional stability of the basic configuration (fuse-
lage 1 with tail 1) and of fuselage 1 with tail 4 is compared with the
stability of two transport-type and two fighter-type airplanes in fig-
ure 11 for the purpose of showing how the directional stability of the
tandem overlap helicopter fuselage model tested in this investigation
compares with the directional stability of practical airplane configura-
tions. The data for the transport-type airplanes were taken from refer-
ences 6 and 7 and for the fighter-type airplanes from references 8 and 9.
The directional-stability results of the fighter-type airplanes used for
this comparison were assumed to have a linear variation up to about 10°
of sideslip. From figure 11 it can be seen that the directional stability
of fuselage 1 with tail 4 has approximately the same magnitude as the
directional stability of these airplanes.

Effect of horizontal tail.- The results of tests made to determine
the influence of a particular horizontal tail on the directional stability
of the basic overlap-type fuselage model at -10° angle of attack are
given in figure 12. The rectangular horizontal tail (b = 15.30 inches,
c = 4.60 inches, and A = 3.33) employed for this test was set at an
angle of incidence of 7.5° and located near the center of the vertical
tail as shown in figure 2(b). No important effect of a horizontal tail
on the directional stability characteristics was noted.

Directional Stability of Nonoverlap-Type Fuselage

Basic model.- Fuselage 3 with tail 5 (F_3T_5) is directionally unstable
for angles of attack of 10° and 30° and directionally stable for angles
of attack of -10° and -30° (see figs. 13 and 14). A comparison of the
sum of the fuselage-alone and tail-alone results ($F_3 + T_5$) with the
results for the basic model (F_3T_5) indicates that there is a sizable
amount of aerodynamic interference between the fuselage and tail. A
summary plot of this interference is presented as figure 15. From this
figure it can be seen that the interference is of considerable magnitude
and generally destabilizing. Tuft-grid pictures of the air flow behind
the nonoverlap-type fuselage at two angles of attack and three angles of
sideslip, which show the nature of the interference discussed, are pre-
sented in figure 16. The asymmetric vortex disposition shown in these
photographs for 20° angle of attack produces an unfavorable sidewash on
the vertical tail. The rate of change of this asymmetric vortex system
with angle of sideslip probably accounts largely for the apparently low
vertical-tail effectiveness of this model.

The directional-stability derivative C_{n_β} of the nonoverlap-type
fuselage alone is compared in figure 17 with the directional-stability
derivative C_{n_β} of the overlap-type fuselage and of fuselage 4 of ref-
erence 10 in order to illustrate the large variation of directional sta-
bility with angle of attack exhibited by the nonoverlap-type fuselage.
From this figure it can be seen that C_{n_β} for the nonoverlap fuselage
varies from a small stable value at -30° to a large unstable value at 30°.
This behavior is an important factor in the stability of the fuselage-
tail combination, of course, and is probably considerably affected by
the vortex patterns shown in figure 16.

Effect of spoilers.- The effects of certain spoiler configurations
on the directional stability of the nonoverlap-type fuselage are presented
in figures 18 and 19. The use of spoiler configurations 1, 2, or 3 on
the fuselage generally stabilized the unstable fuselage-tail configura-
tion for α = 10° and 30°. Some tests in the Langley free-flight tunnel
have indicated a similar result for the overlap-type fuselage. The
fuselage-tail configuration for α = -10° and -30° was directionally
stable (see figs. 18 and 19), and the addition of spoilers to the basic
configuration generally had a negligible effect over most of the side-
slip range except for α = -30°, at which value certain spoiler config-
urations caused directional instability for small sideslip angles. The
spoilers on the fuselage probably destroy the potential flow about the
fuselage and thereby reduce the unstable fuselage yawing moment. The
fact that there was no increase in directional stability at negative
angles of attack is recognized; however, the scope of the present tests
does not appear to be sufficient to explain this effect. The spoilers,
as would be expected, gave some increase in drag, and a comparison of
the drag coefficient for the basic model configuration with and without
spoiler 1 is presented in figure 20.

Effect of vertical-tail modifications.- The effect on the directional
stability at 10° angle of attack of increasing the distance between the
basic vertical tails (tail 5, A = 1.3) to minimize the effect of the
fuselage vortices is presented in figure 21. This modification results
in a slight improvement in directional stability. The effect at 10° angle
of attack of an increase in the vertical-tail aspect ratio is presented
in figure 22. Little improvement in stability was obtained with this
modification. However, when the distance between the other vertical
tails (tail 6, A = 2.2) was increased, the model was directionally stable
for sideslip angles to ±10° (see fig. 23). Lowering these tails approxi-
mately 14 percent of the horizontal-tail span made little further
improvement.

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CONCLUSIONS

The results of a low-speed investigation in the Langley stability tunnel of the directional stability characteristics of an overlap- and a nonoverlap-type tandem helicopter fuselage indicate the following conclusions:

1. The original overlap-type fuselage model was found to be directionally unstable at angles of attack of 10°, -10°, and -20° for angles of sideslip to ±6° or less. This instability was found to result from an insufficient contribution of the original vertical tail (which was approximately 35 percent chord in thickness) to the directional stability. This failure of the vertical tail to make a sufficient contribution to the directional stability was believed to be associated with separation caused by the adverse pressure gradient over the relatively thick rear portion of the vertical tail and fuselage.

2. Either blunting the trailing edge of the original vertical tail of the overlap-type fuselage or substituting a thin tail (which was 4 percent chord in thickness) for the original tail resulted, generally, in a directionally stable fuselage-tail arrangement.

3. The nonoverlap-type fuselage model was directionally unstable for certain positive angles of attack throughout the sideslip range. This instability was found to result from a low vertical-tail effectiveness and a large variation of the fuselage-alone directional-stability parameter C_{n_β} with angle of attack. Both of these factors were found to be associated with the rate of change with sideslip angle of an asymmetric trailing-vortex system that existed on the fuselage.

4. The use of spoilers located around the nose of the fuselage was the only effective means found, without resorting to major design changes, for making the nonoverlap-type fuselage directionally stable.

Langley Aeronautical Laboratory,
    National Advisory Committee for Aeronautics,
        Langley Field, Va., February 24, 1954.

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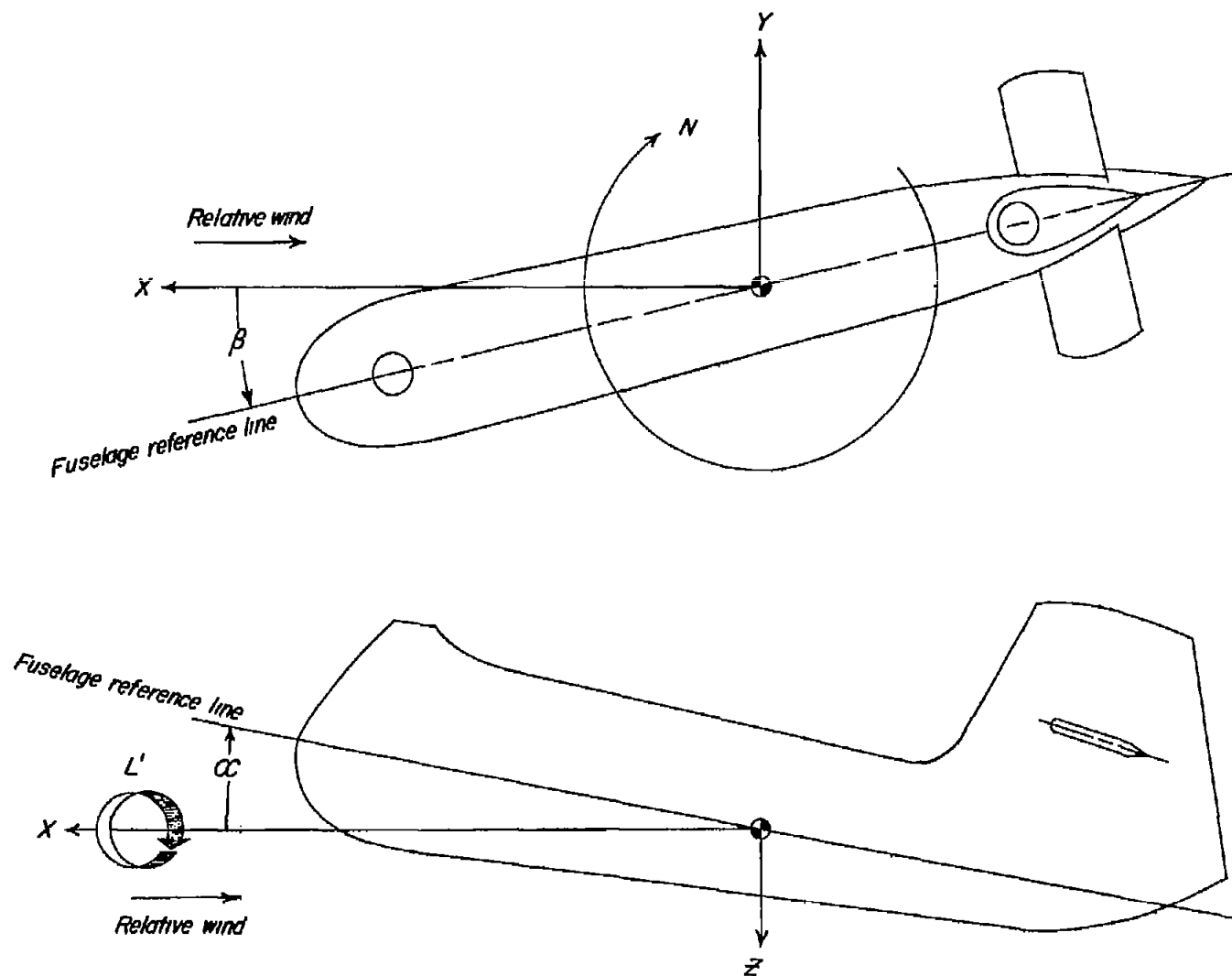
Figure 1.- System of wind axes. Arrows indicate positive direction of forces, moments, and angles.
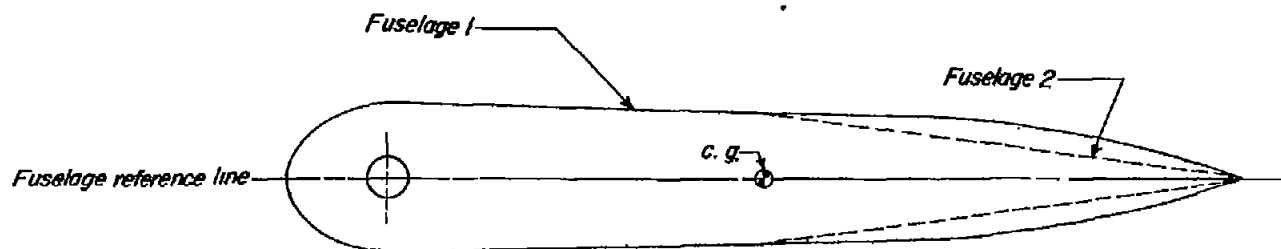
(a) Plan view showing modification made to basic fuselage (fuselage 1)
in order to obtain fuselage 2.
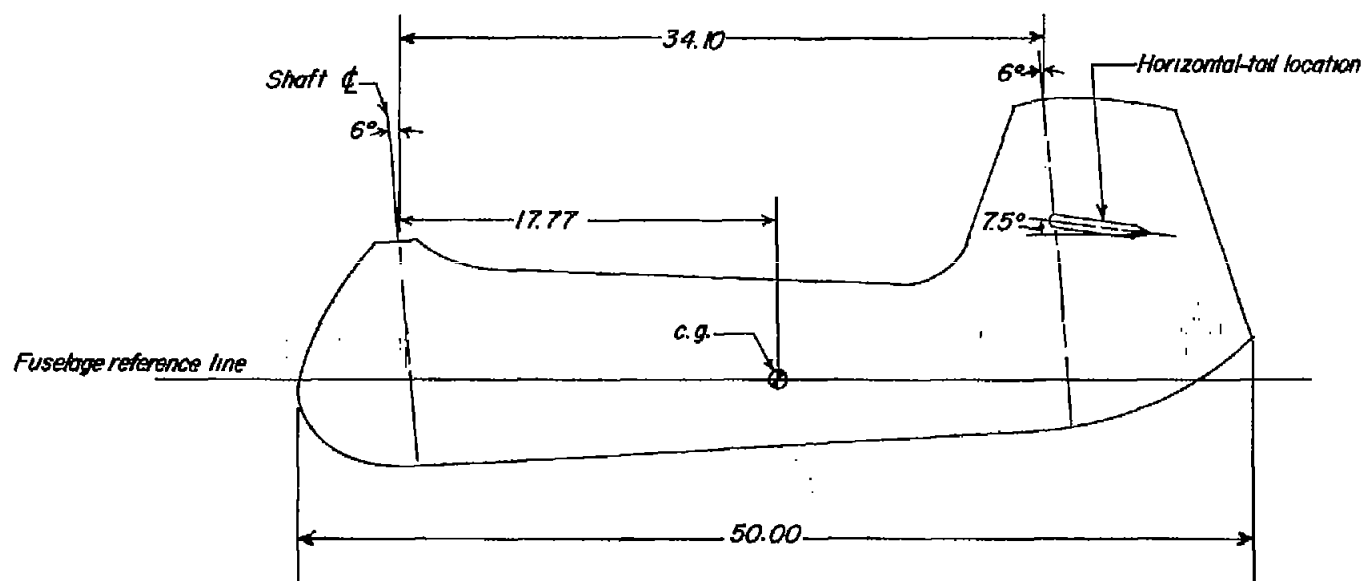
(b) Side view of basic fuselage and pylon showing location used for
determining influence of horizontal tail.

Figure 2.- Details of overlap-type fuselage models. All dimensions are
in inches.

Tail 1 (t/c = 0.35)   *Tail 2 (t/c = 0.04)*

Fuselage reference line
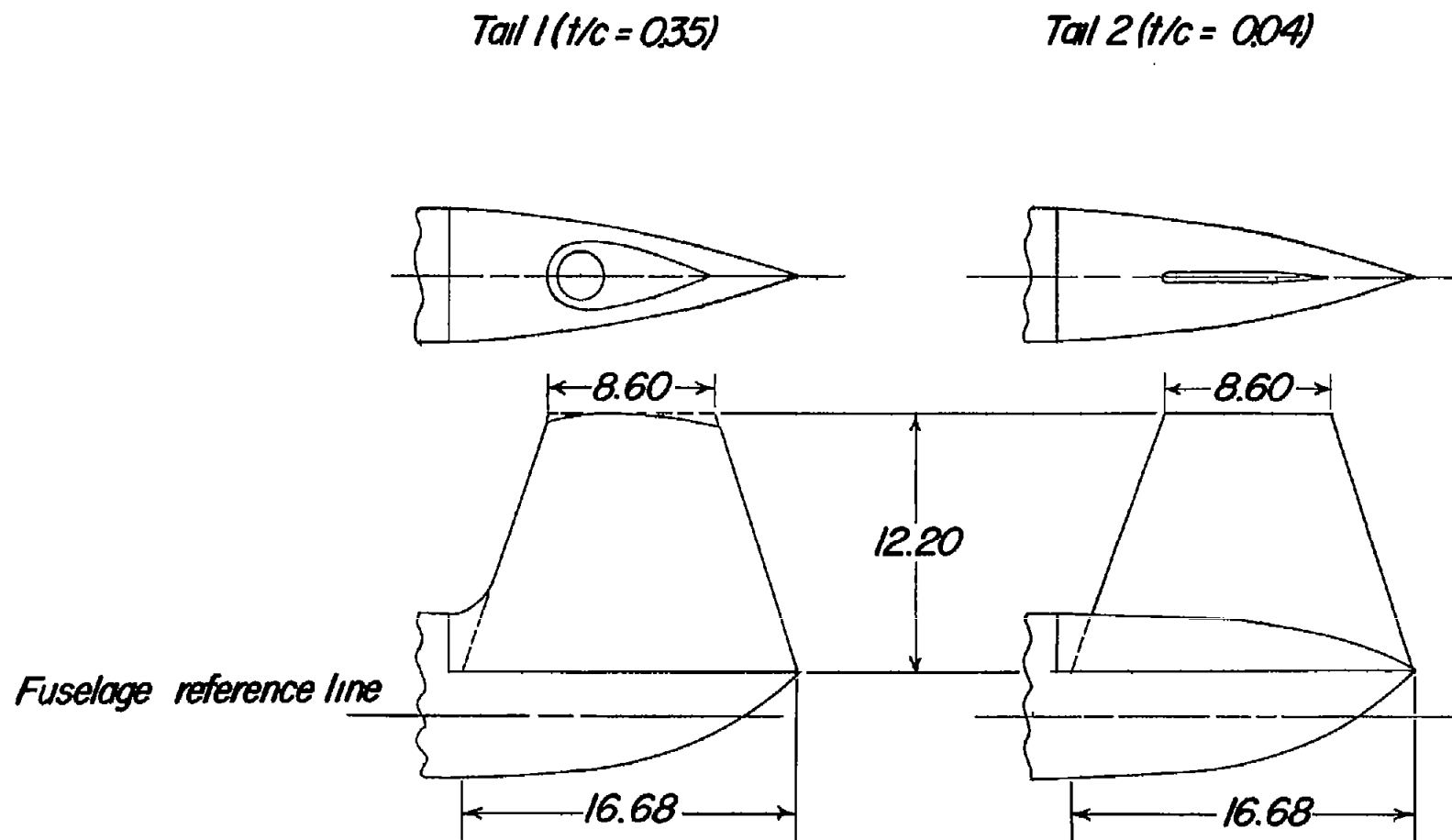
(c) Basic tail and thin tail used in tests of the overlap-type fuselage.

Figure 2.- Continued.

areas added to tail 1 to form tail 3

area added to tail 1 to form tail 4
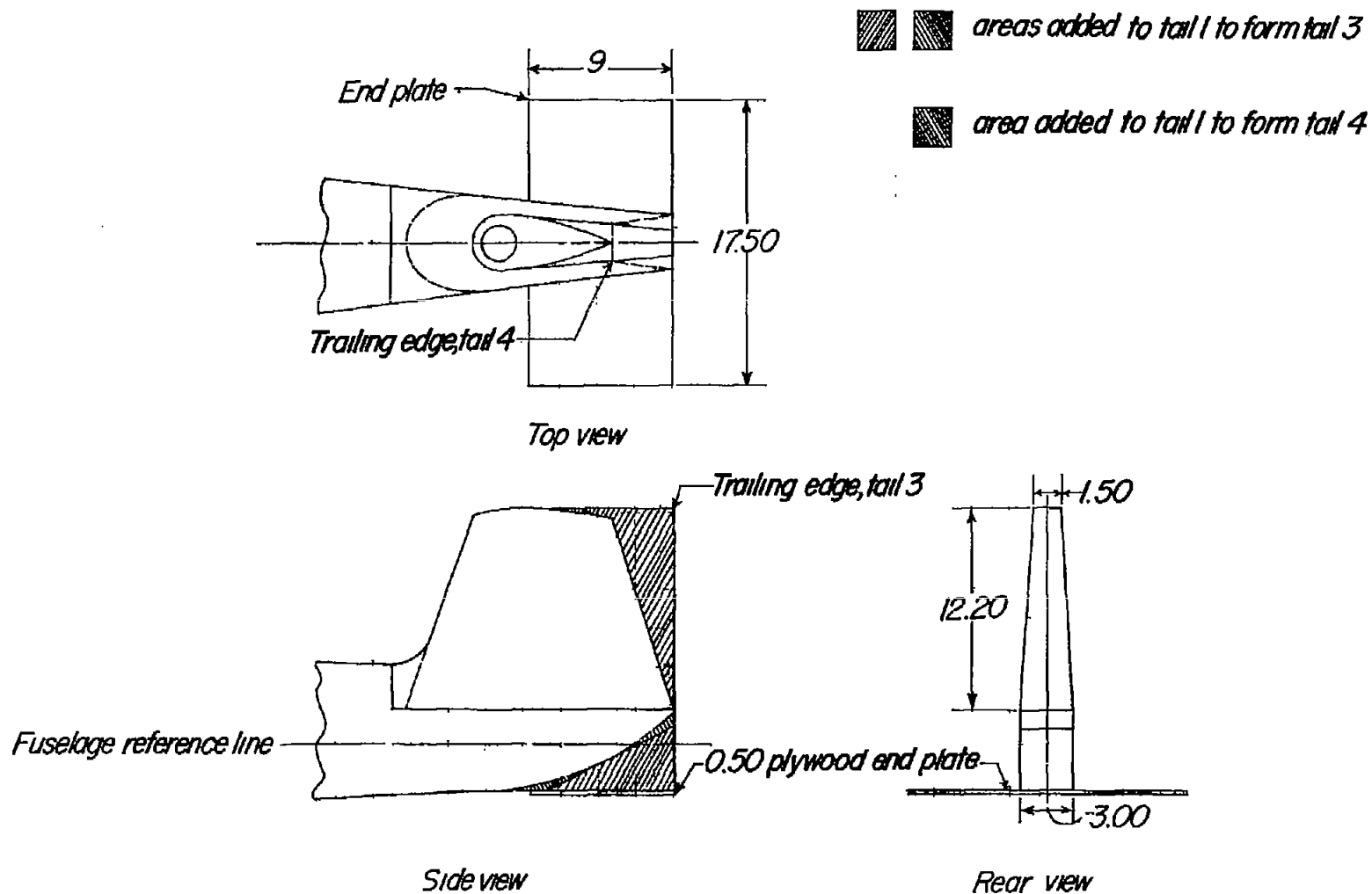
(d) Blunt-trailing-edge pylons (tails 3 and 4) and end plate.

Figure 2.- Concluded.
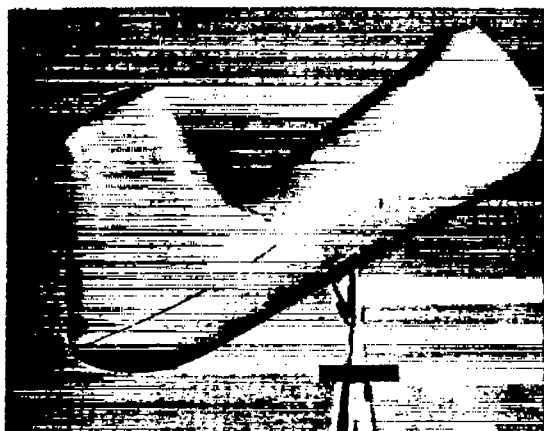
(a) Tail 1.   (b) Tail 2.

(c) Tail 3.   (d) Tail 4.

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Figure 3.- Views of overlap-type fuselage model.

Fuselage 3

10.00

Tail 5 (see fig. 4(b))

56.48

25.40

6.95

c.g.

Fuselage
reference line

13.59
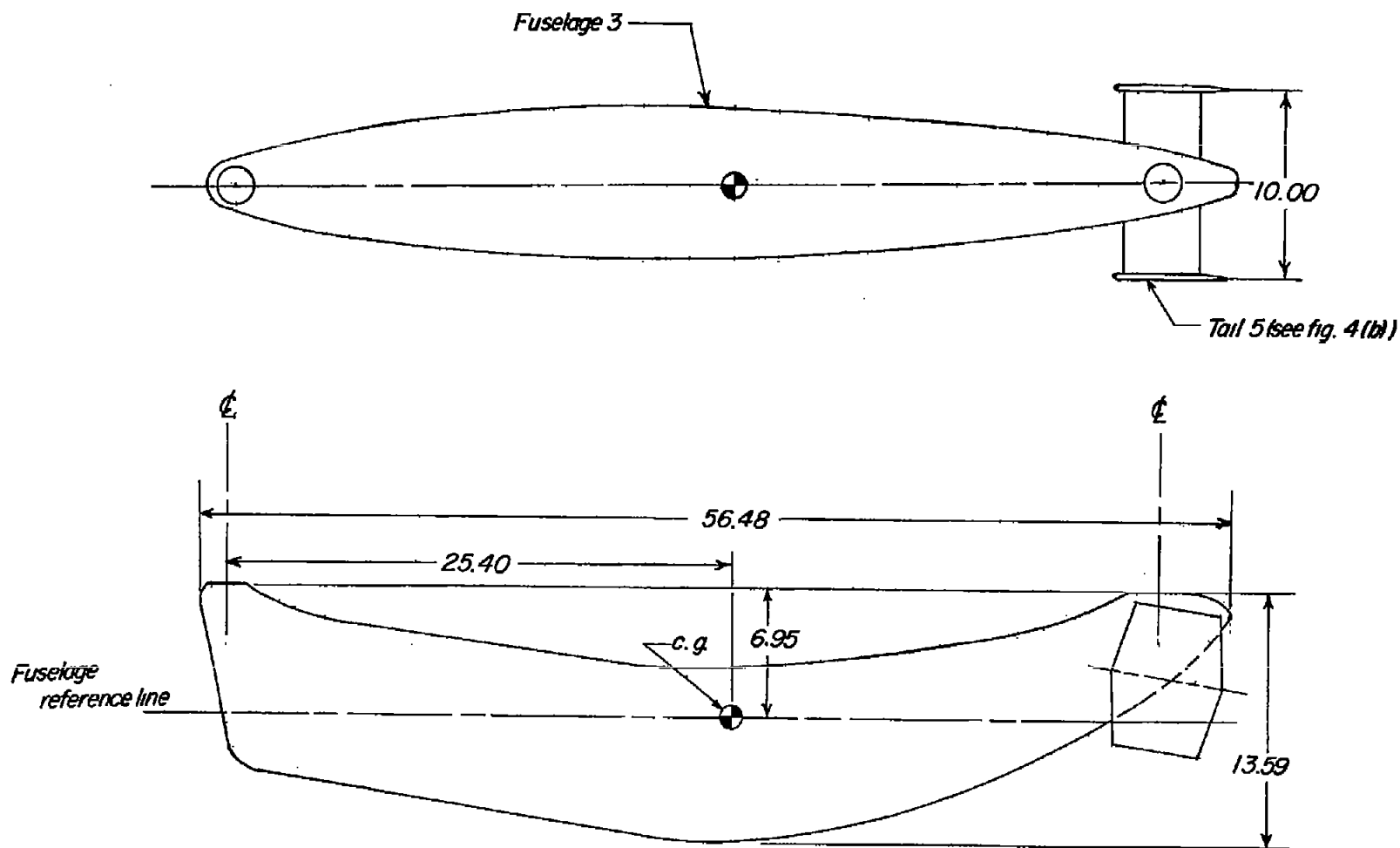
(a) Fuselage with basic tails.

Figure 4.- Details of nonoverlap-type fuselage models. All dimensions
are in inches.

Tail 5   *Tail 6*

Aspect ratio 1.3   Aspect ratio 2.2
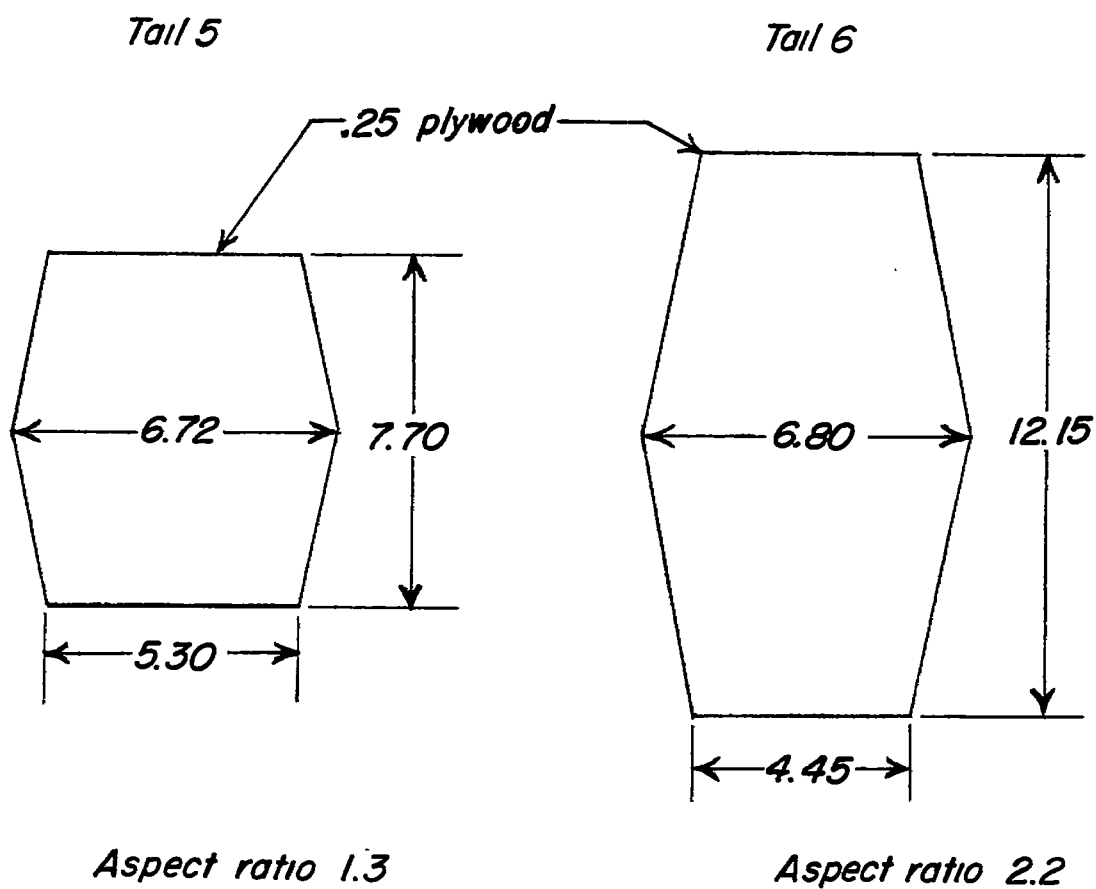
(b) Basic and increased-aspect-ratio tails.

Figure 4.- Concluded.
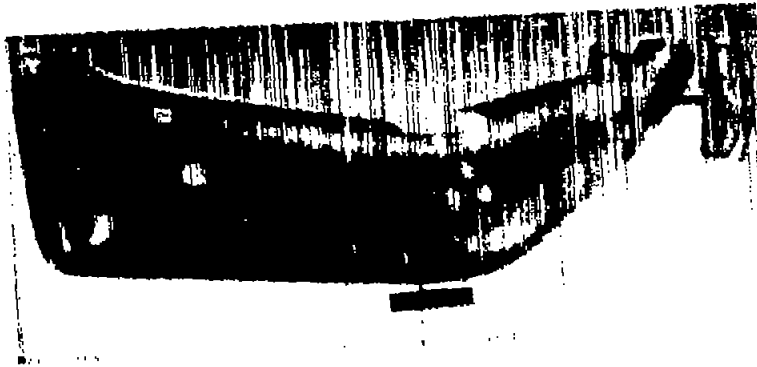
(a) Clean configuration.

(b) Spoiler 1.

(c) Spoiler 2.
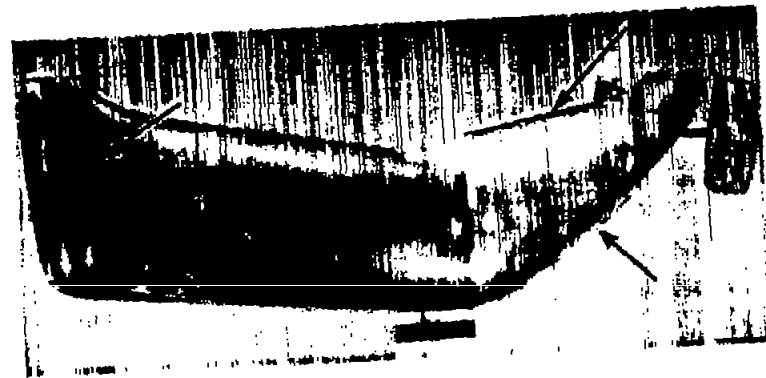
(d) Spoiler 3.

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Figure 5.- Views of nonoverlap-type fuselage model.

○ Fuselage I + tail I (Fⱼ Tⱼ)
□ Fuselage I alone (Fⱼ)
◇ Tail I alone (Tⱼ)

—— Addition of fuselage I alone and tail I
alone curves (Fⱼ + Tⱼ)
—— Theoretical tail slope

$\alpha = +10°$ $\alpha = -10°$ $\alpha = -20°$

C_n

.016 .014 .012 .010 .008 .006 .004 .002 0 -.002 -.004 -.006 -.008 -.010 -.012 -.014

-25 -20 -15 -10 -5 0 5 10 15 20 25

β, deg
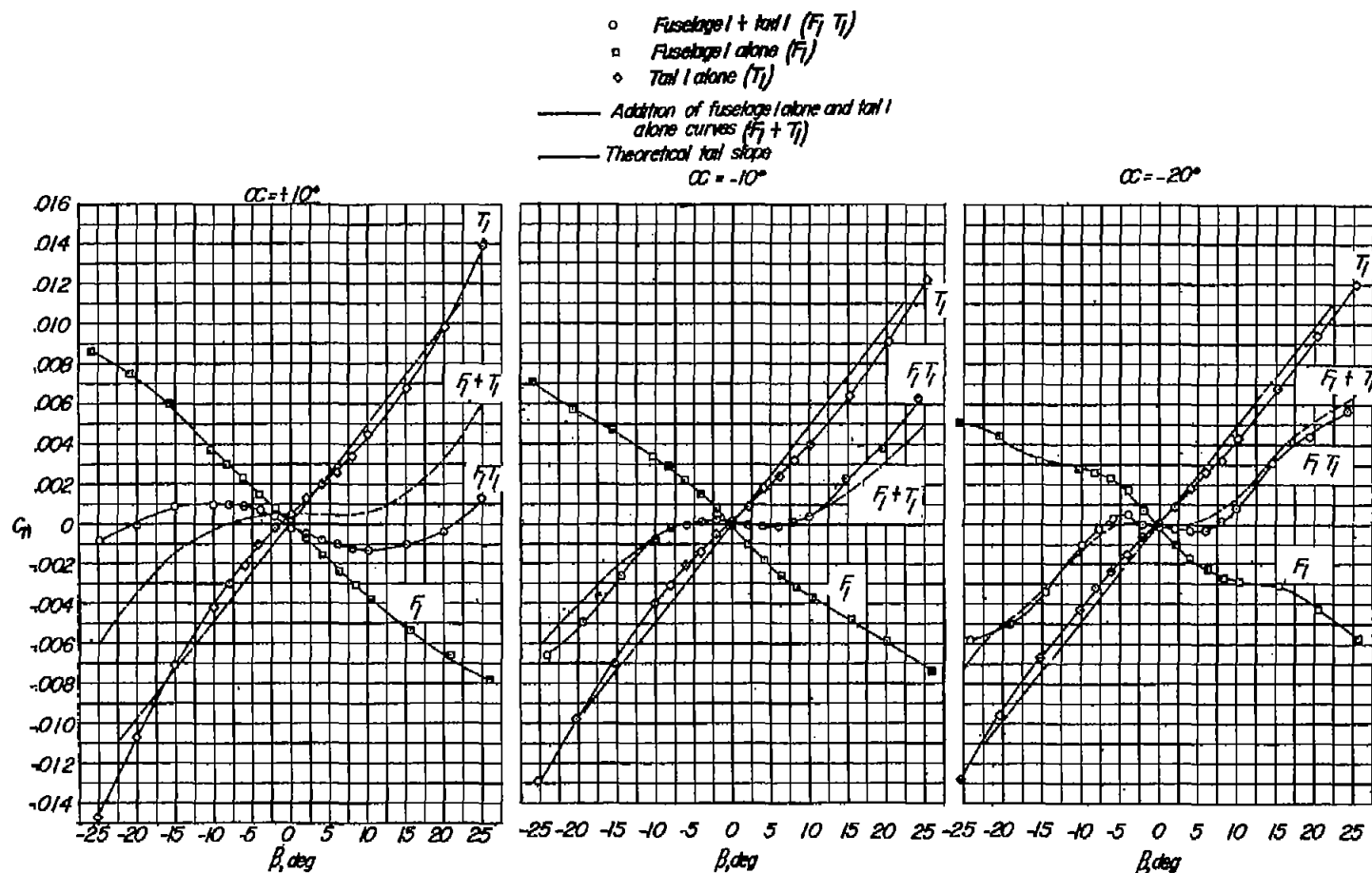
(a) Yawing-moment coefficient.

Figure 6.— Aerodynamic characteristics in sideslip of the unmodified
overlap-type fuselage and vertical tail of 35-percent thickness,
showing the contribution of the fuselage alone and vertical tail
alone for three angles of attack.

(b) Side-force coefficient.

Figure 6.- Continued.
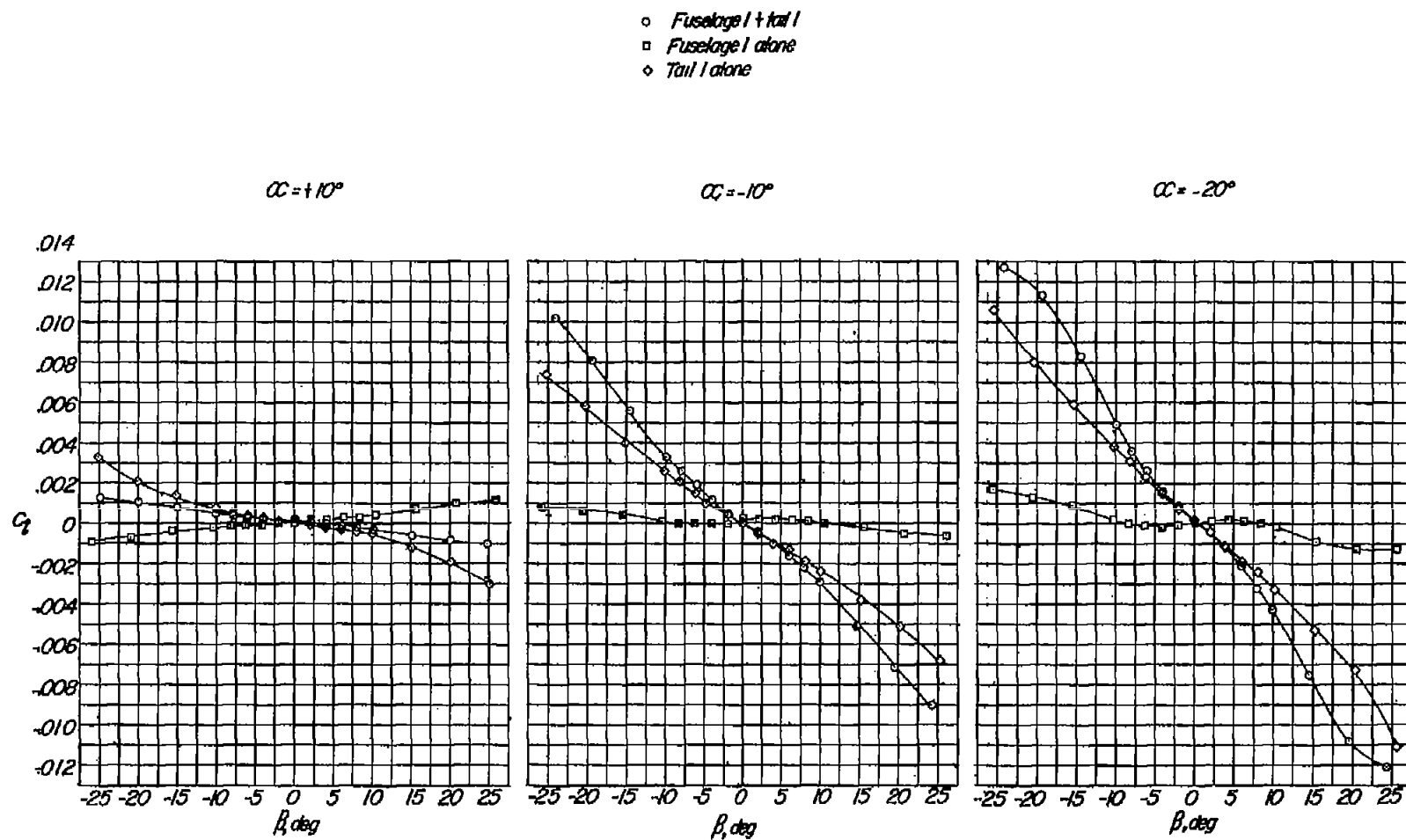
(c) Rolling-moment coefficient.

Figure 6.- Concluded.

o   Fuselage I + tail 2 $(F_1 \, T_2)$
□   Fuselage I alone (F_1)
◇   Tail 2 alone (T_2)
——   Addition of fuselage I alone and tail 2 alone curves (F_1+T_2)
——   Theoretical tail slope
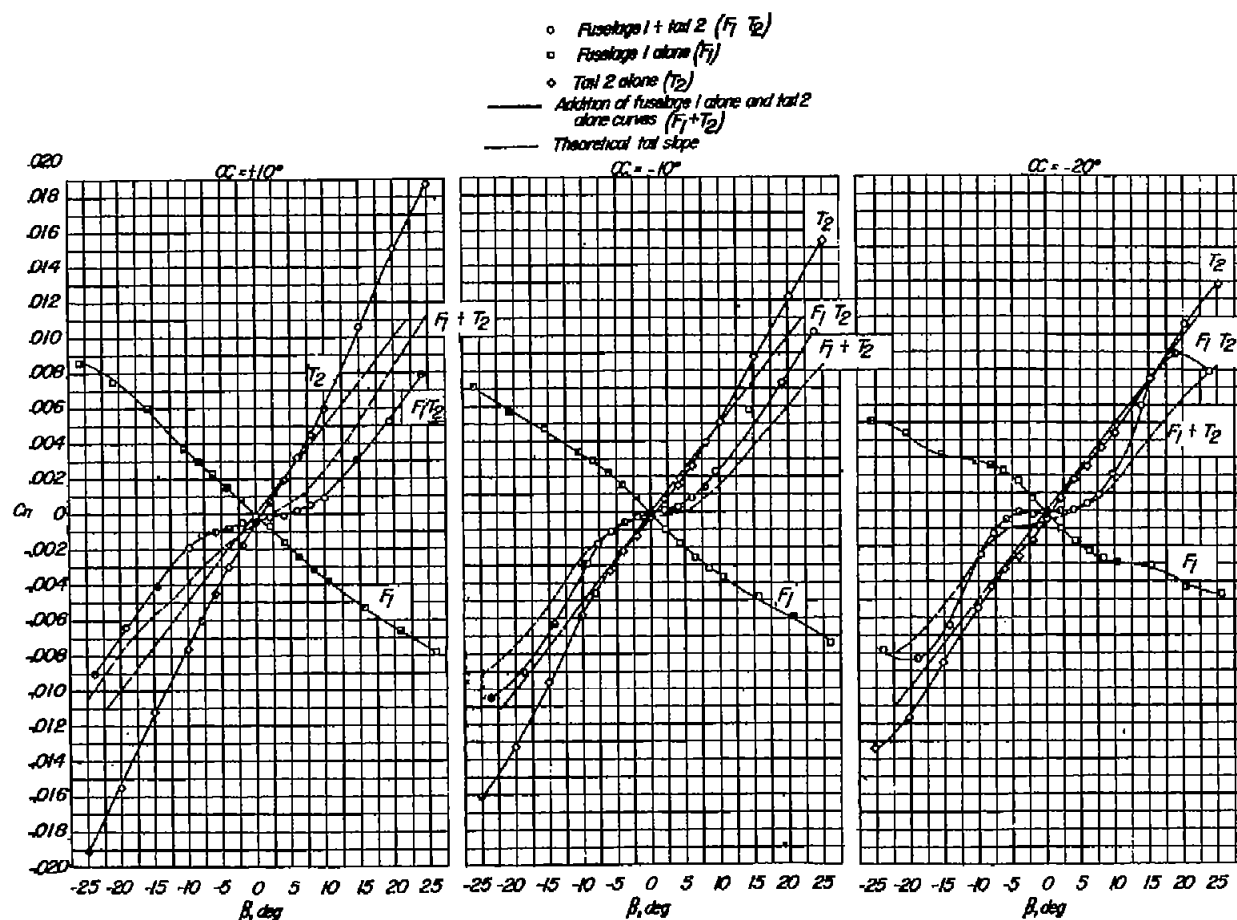
(a) Yawing-moment coefficient.

Figure 7.- Aerodynamic characteristics in sideslip of the unmodified
overlap-type fuselage and vertical tail of 4-percent thickness,
showing the contribution of the fuselage alone and vertical tail
alone for three angles of attack.

(b) Side-force coefficient.

Figure 7.- Continued.
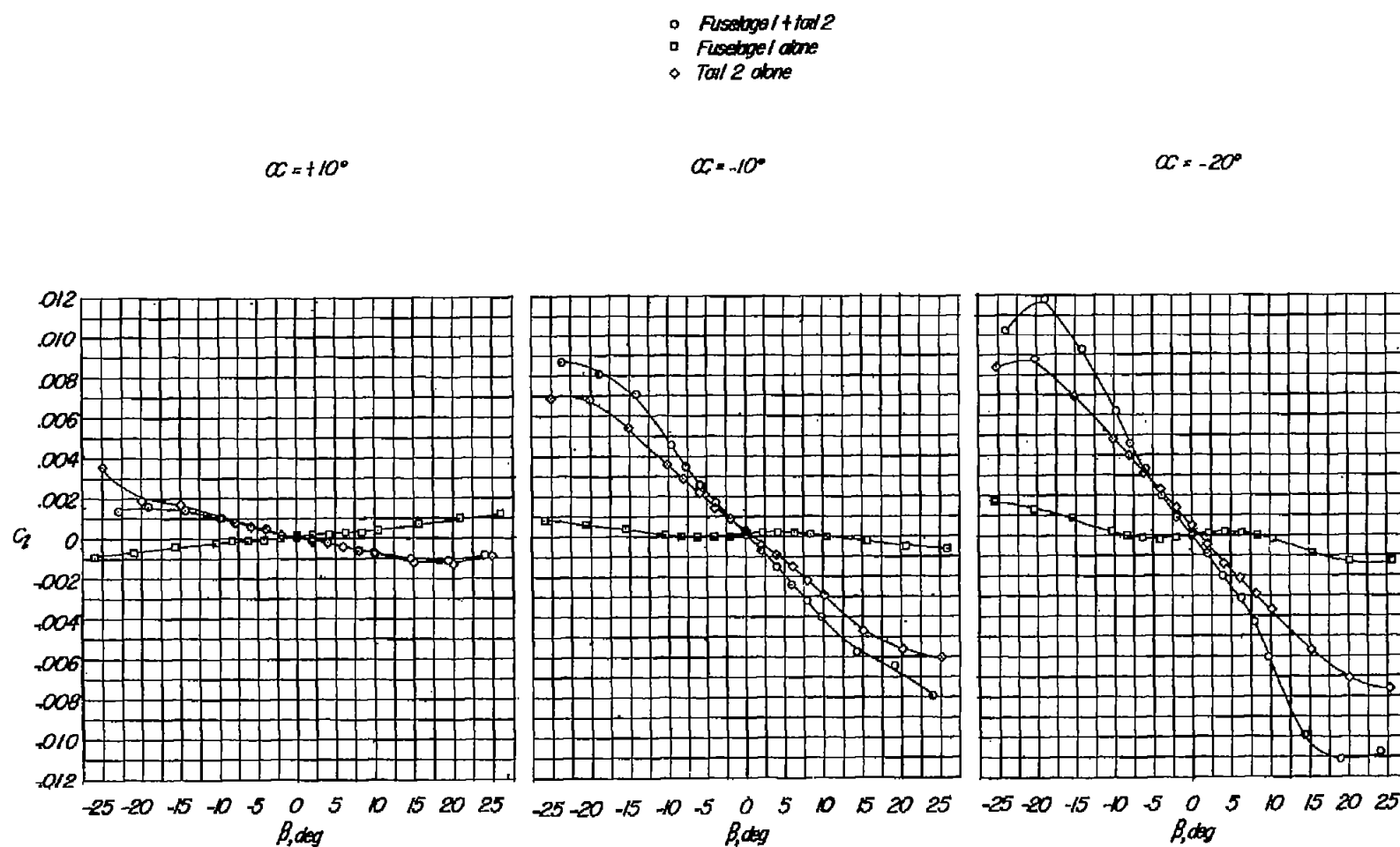
(c) Rolling-moment coefficient.

Figure 7.- Concluded.
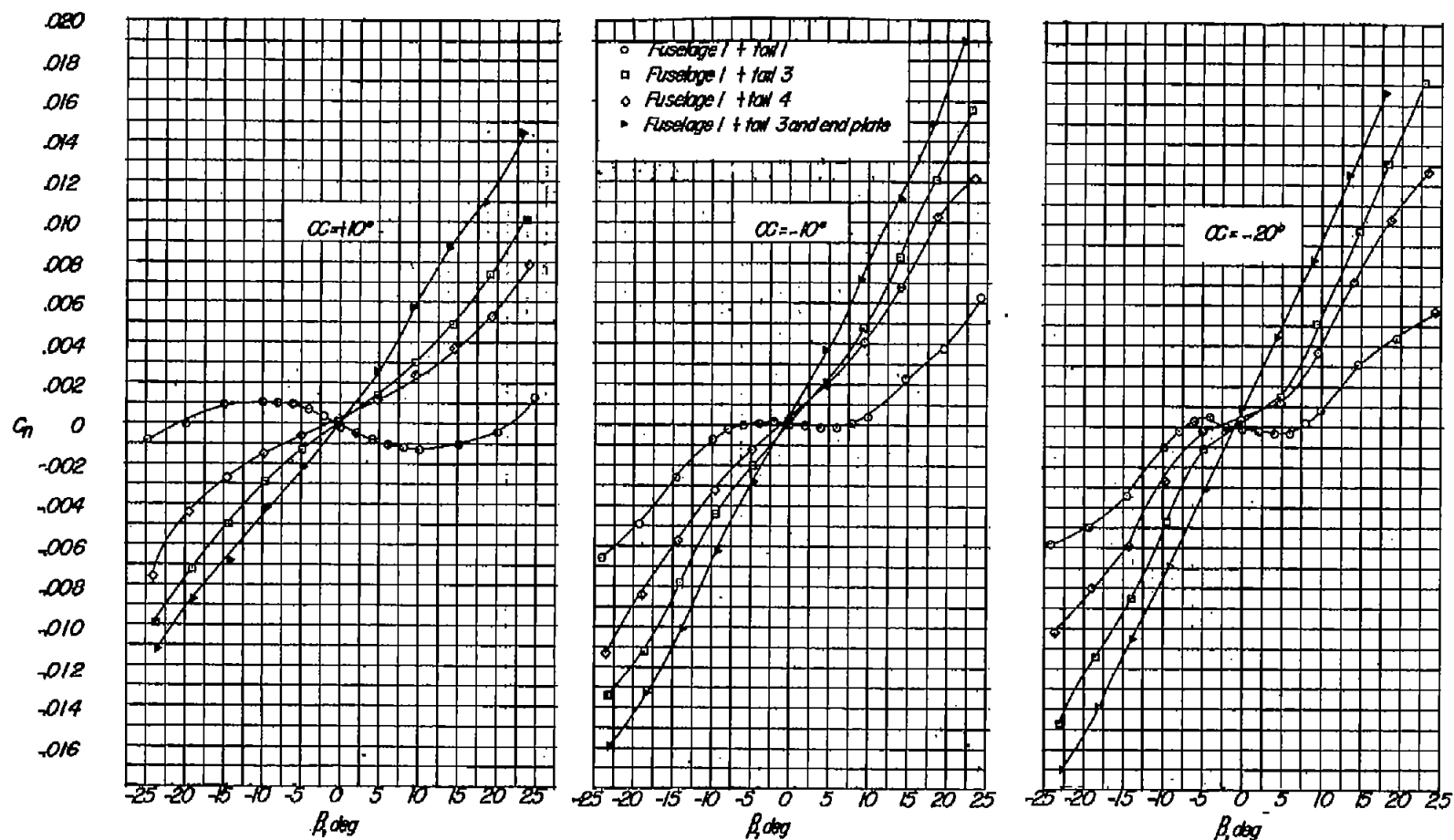
(a) Yawing-moment coefficient.

Figure 8.- Aerodynamic characteristics in sideslip of the unmodified overlap-type fuselage with blunt tail 3, blunt tail 4, and blunt tail 3 with end plate for three angles of attack.

○	Fuselage 1 + tail 1
□	Fuselage 1 + tail 3
◇	Fuselage 1 + tail 4
▷	Fuselage 1 + tail 3 and end plate
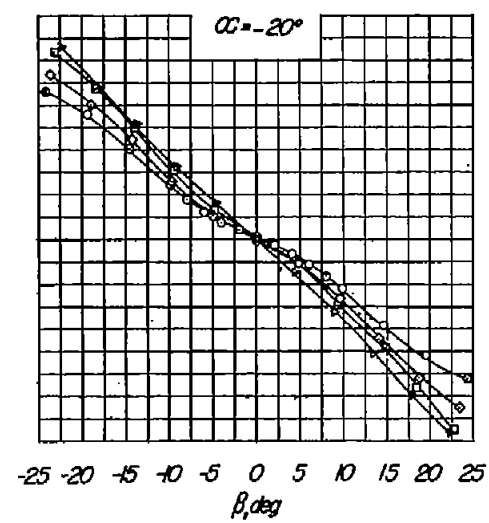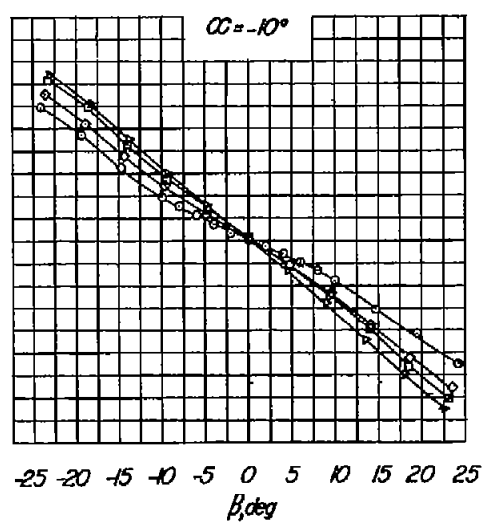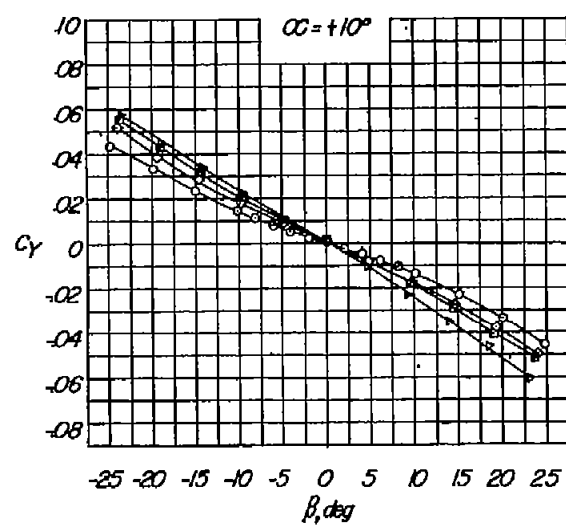
(b) Side-force coefficient.

Figure 8.- Continued.
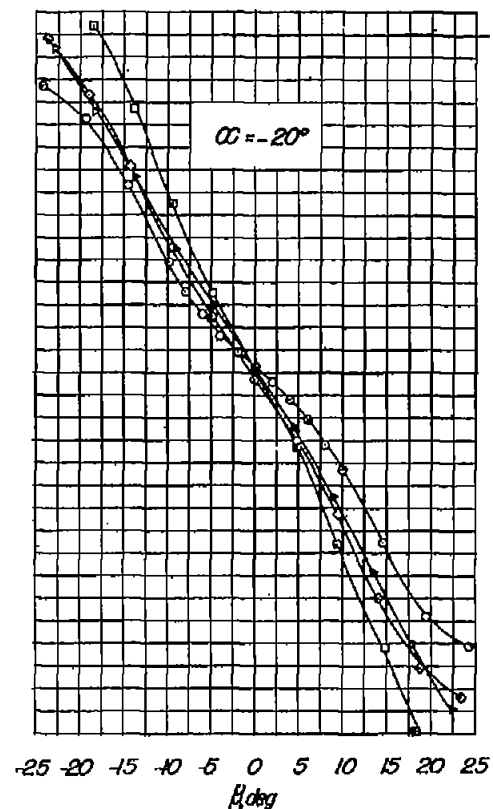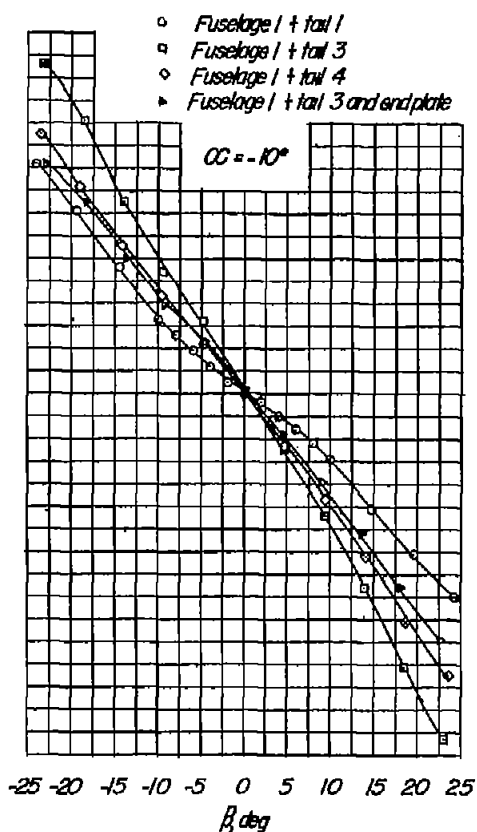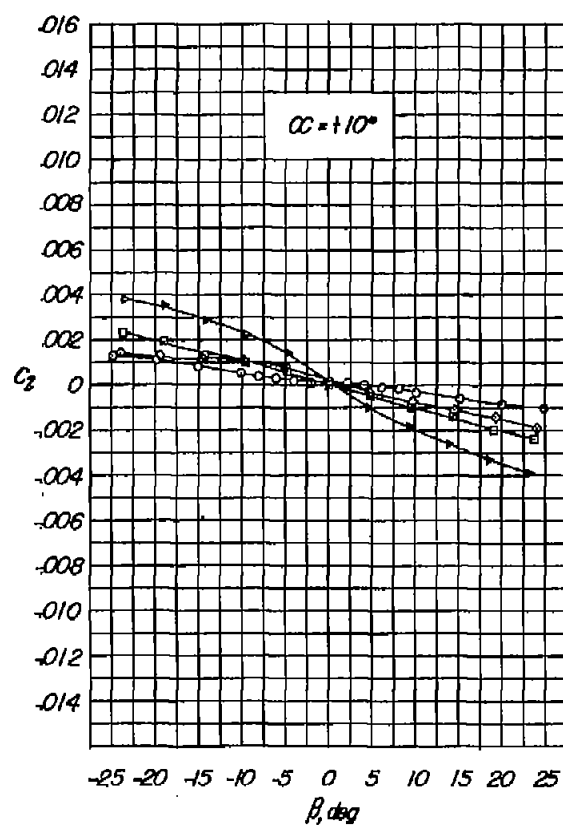
(c) Rolling-moment coefficient.

Figure 8.- Concluded.
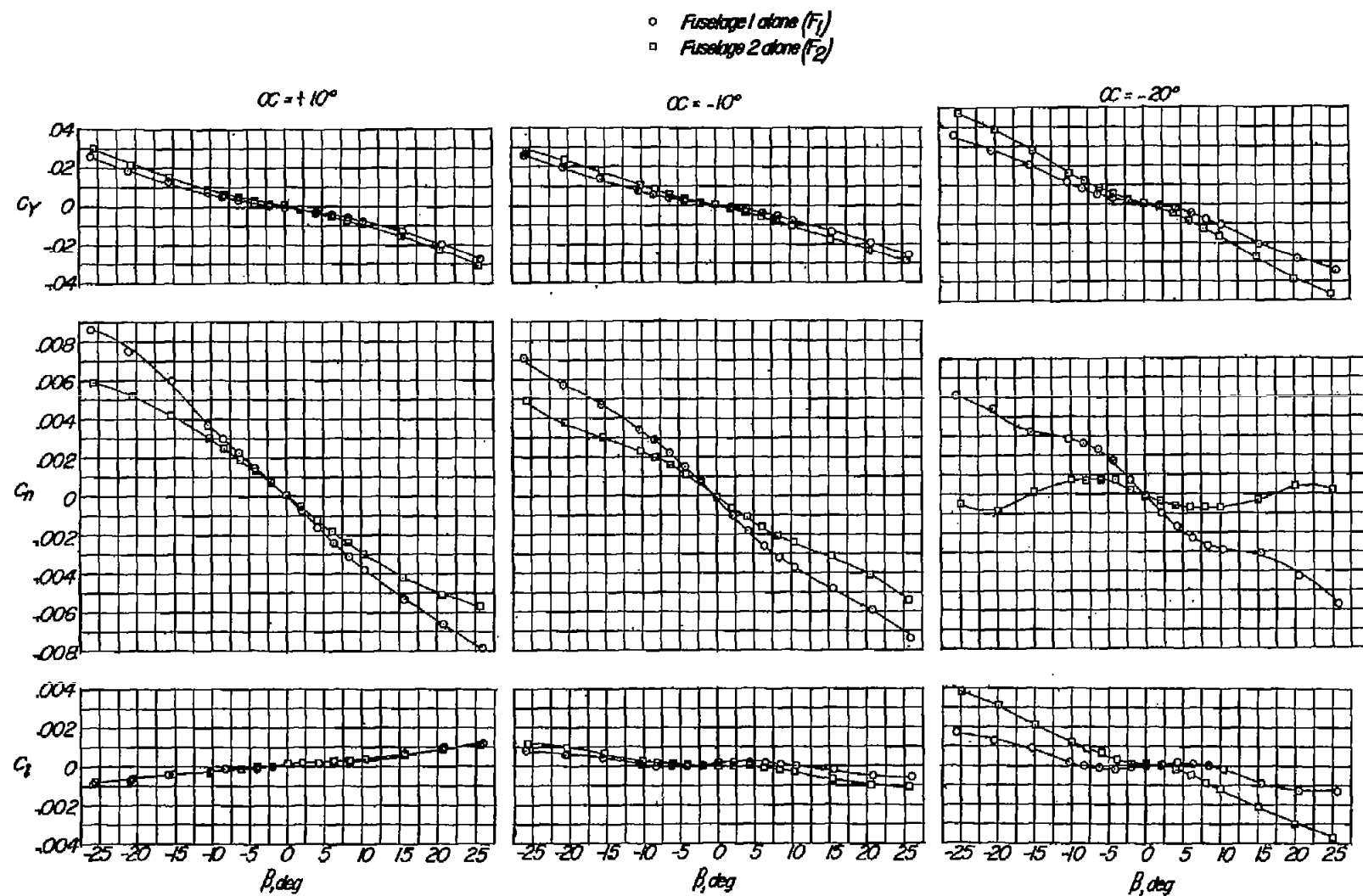
Figure 9.- Aerodynamic characteristics in sideslip of the modified and unmodified overlap-type fuselages for three angles of attack.

(a) Yawing-moment coefficient.
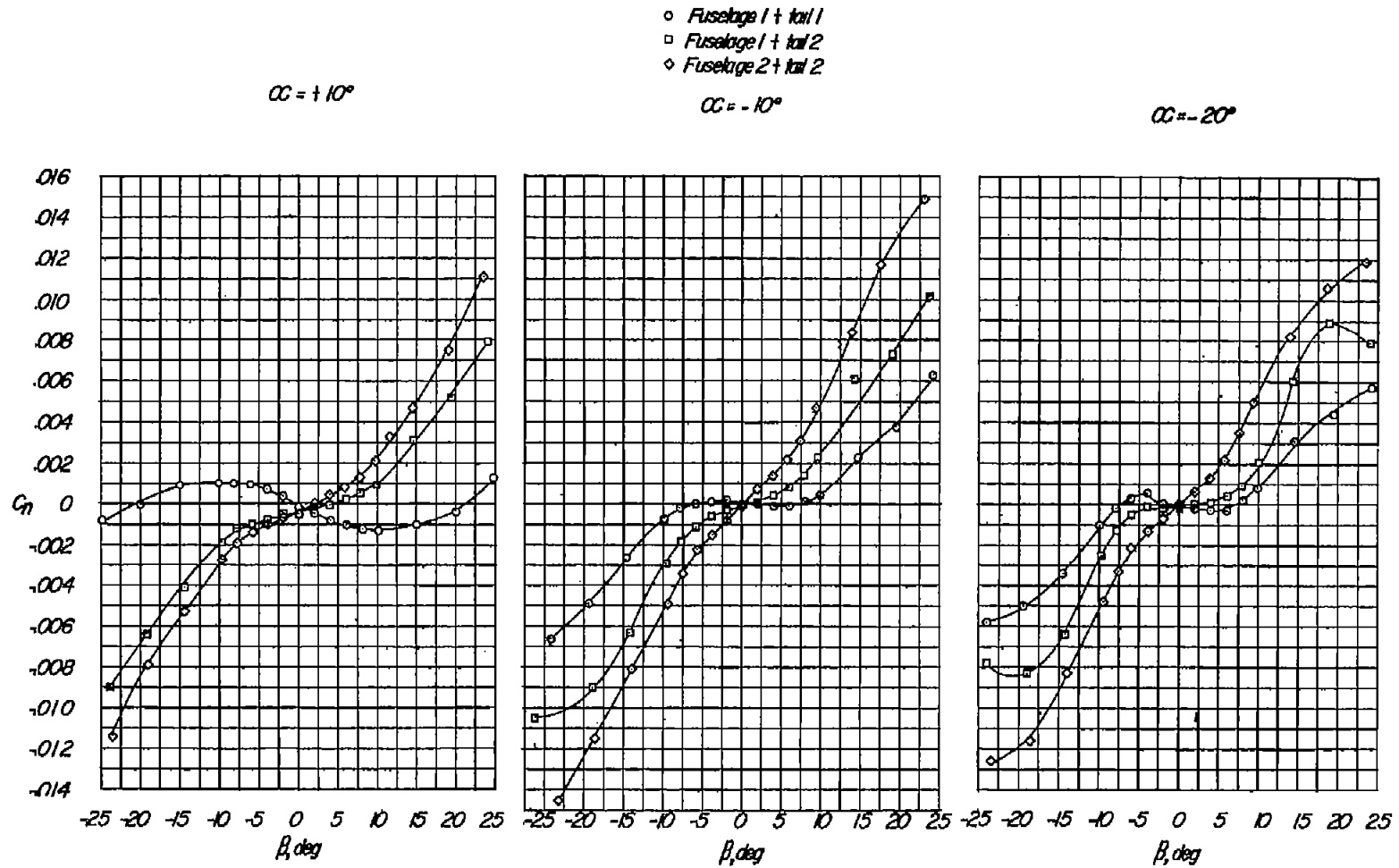
Figure 10.— Aerodynamic characteristics in sideslip, showing effect of vertical-tail thickness on characteristics of modified and unmodified overlap-type fuselage for three angles of attack.

(b) Side-force coefficient.

Figure 10.- Continued.
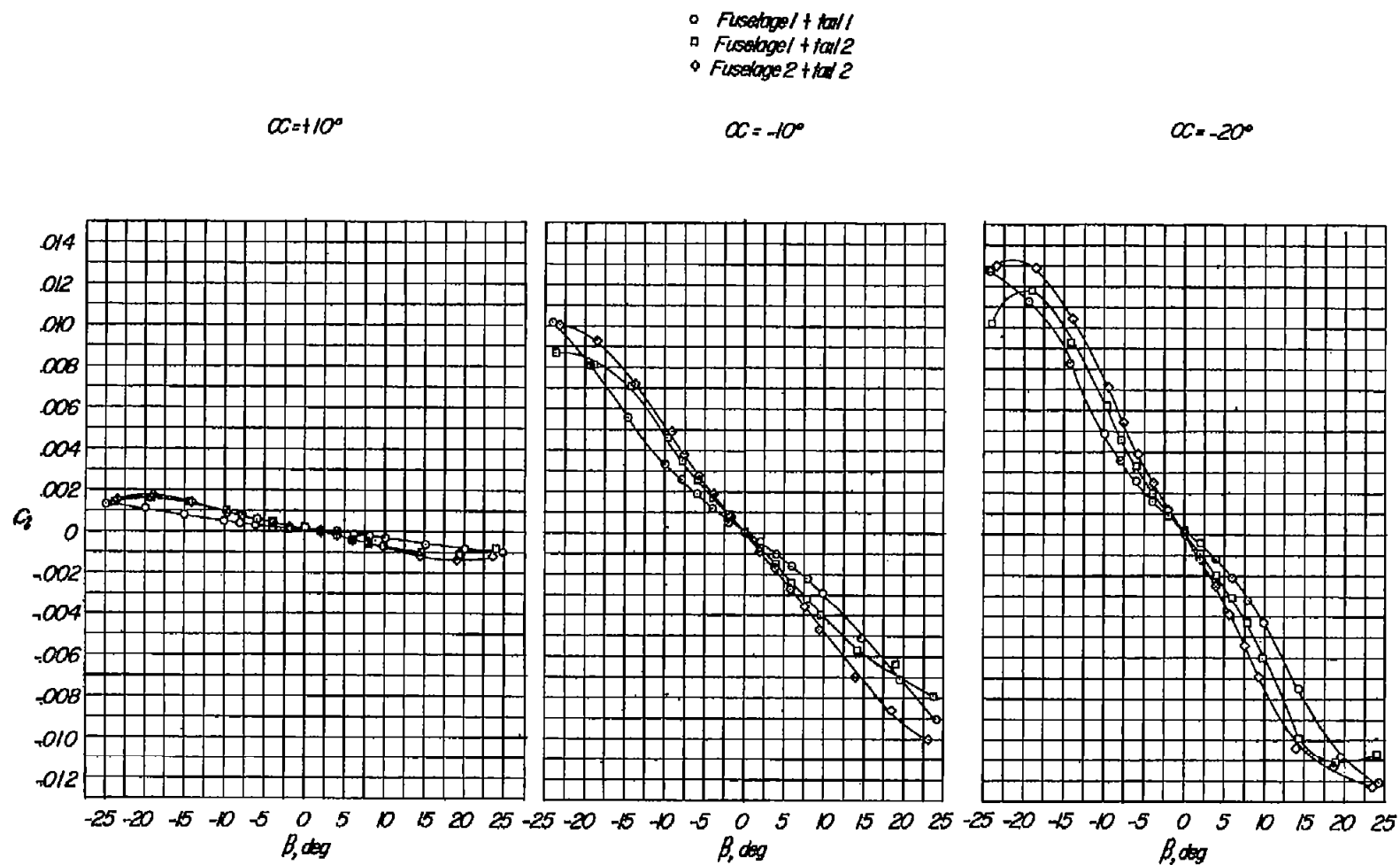
(c) Rolling-moment coefficient.

Figure 10.- Concluded.
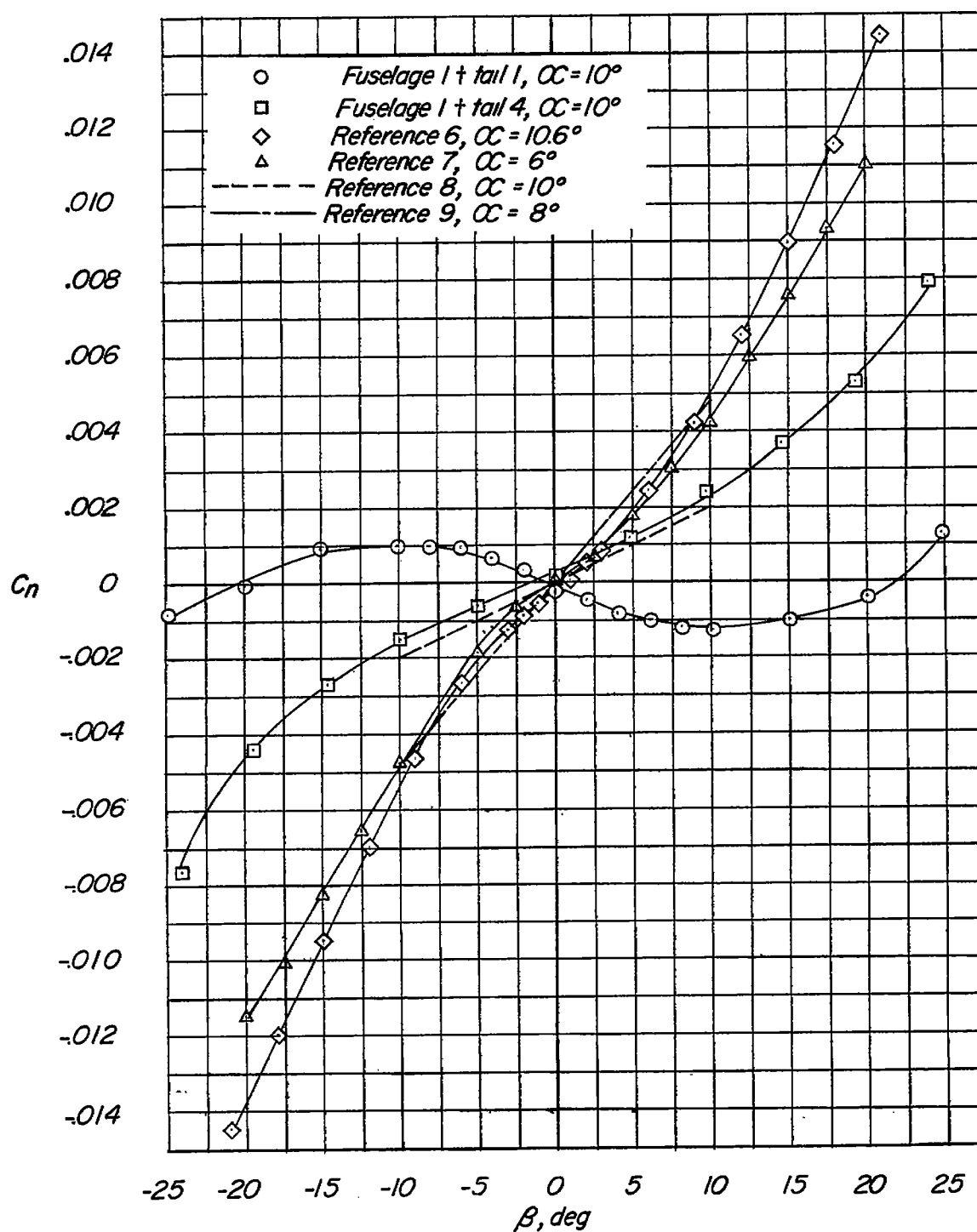
Figure 11.- Comparison of yawing-moment coefficients for several airplanes with yawing-moment coefficients for the overlap-type fuselage with original and blunt-trailing-edge vertical tails.
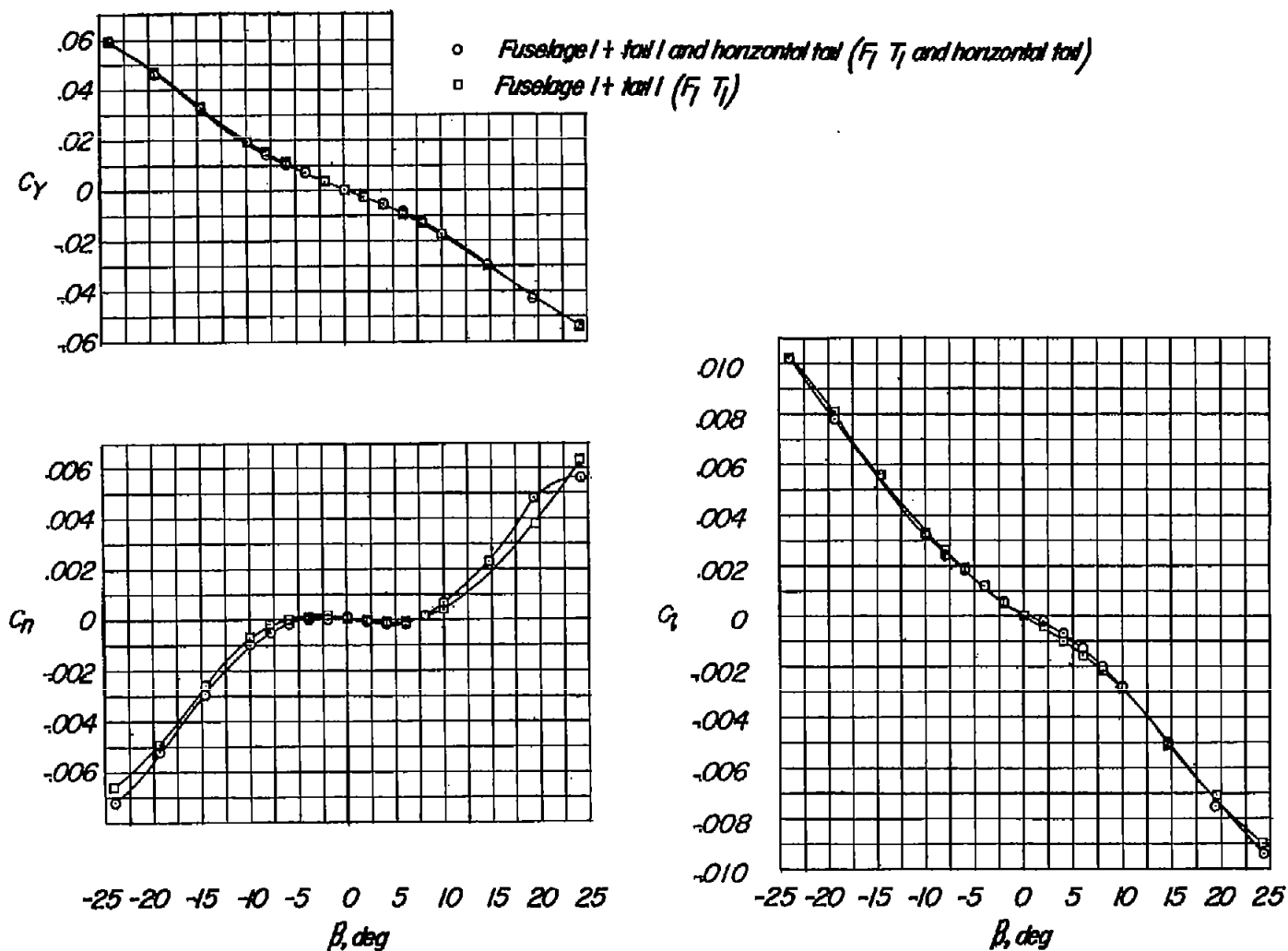
Figure 12.- Comparison of the aerodynamic characteristics in sideslip of the unmodified overlap-type fuselage and vertical tail with and without a horizontal tail. $\alpha = -10^\circ$.
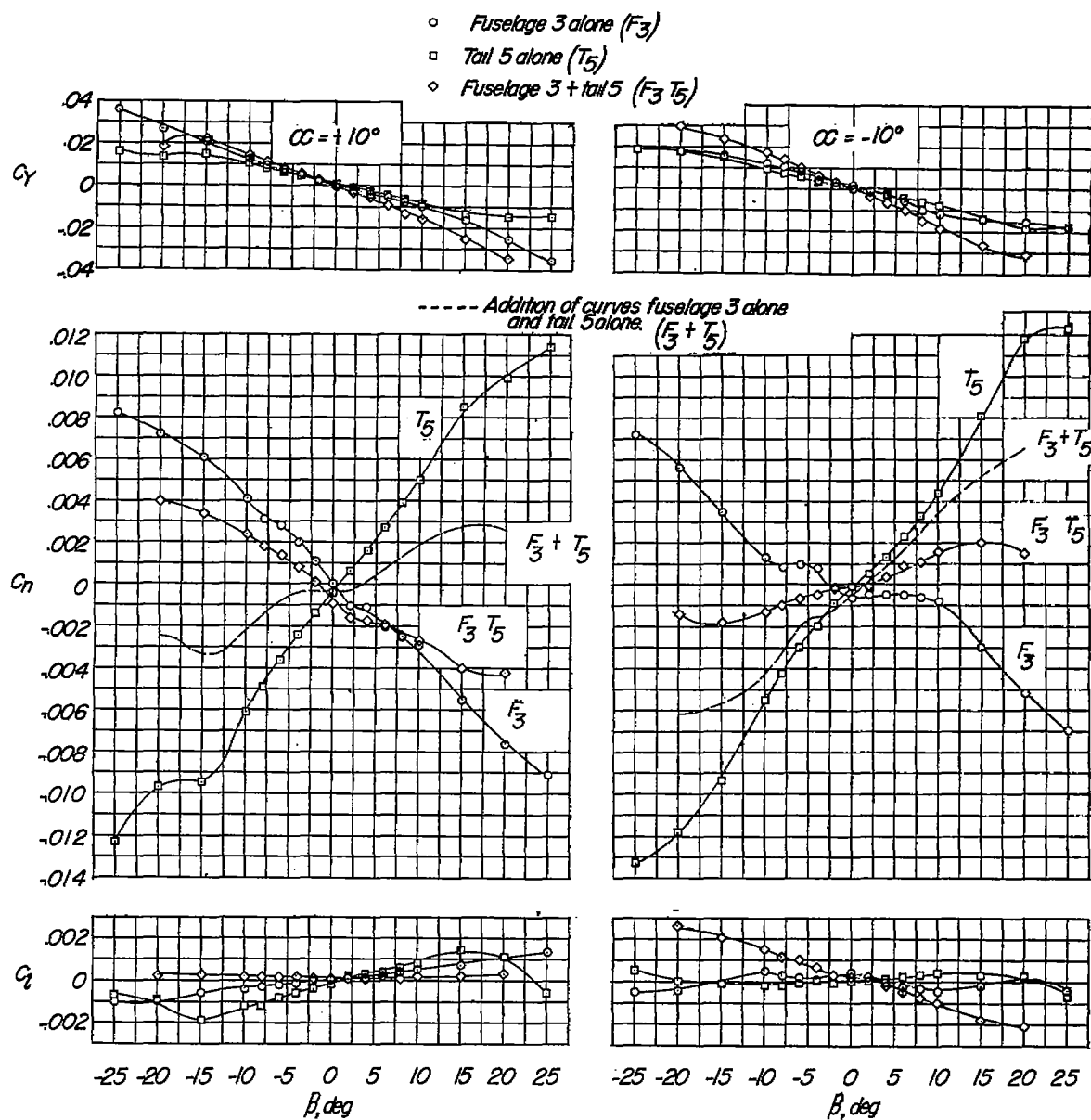
Figure 13.- Aerodynamic characteristics in sideslip of the nonoverlap-type
  fuselage and basic tail, showing the contribution of the fuselage alone
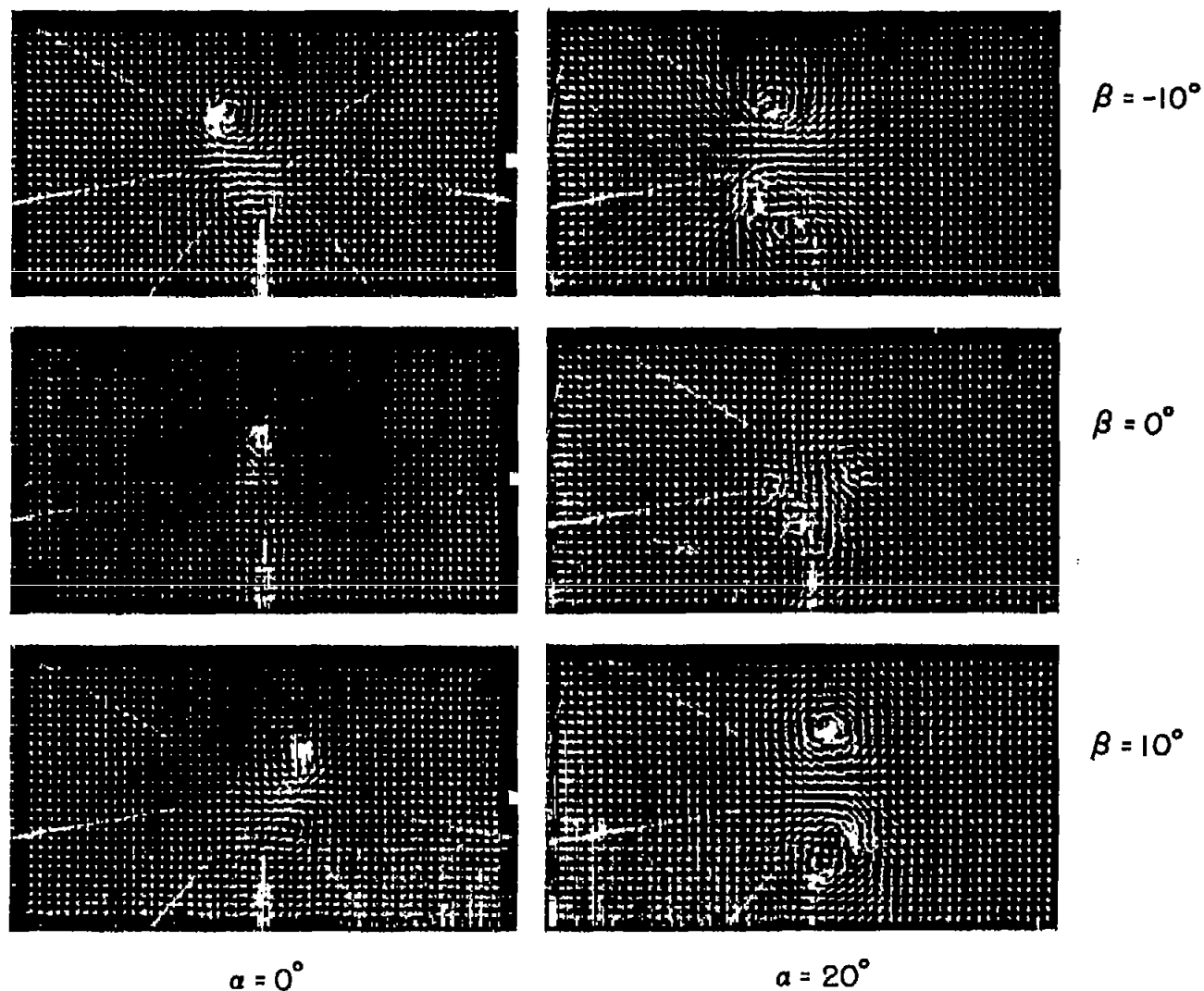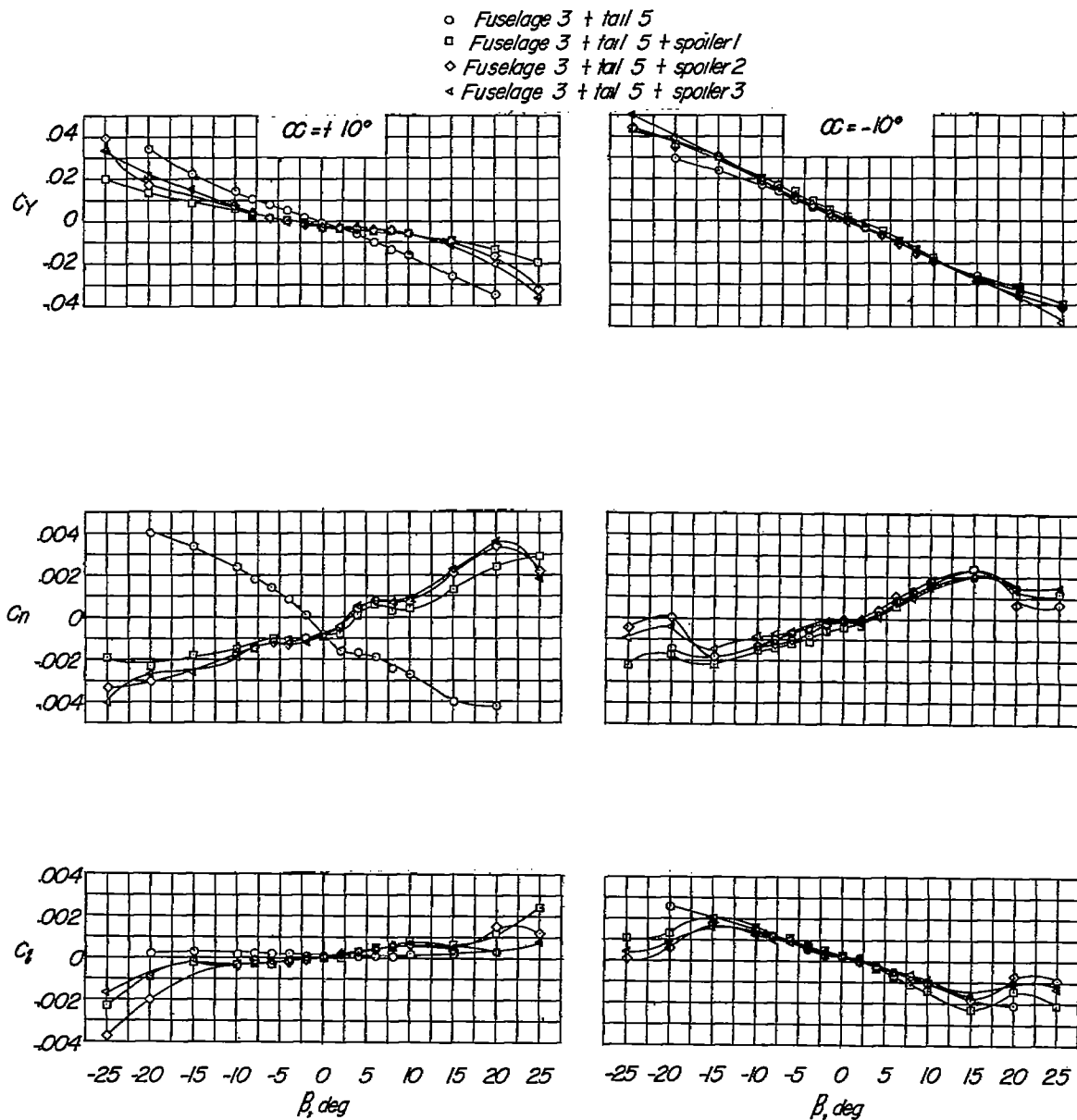 and tail alone for angles of attack of 10° and -10°.
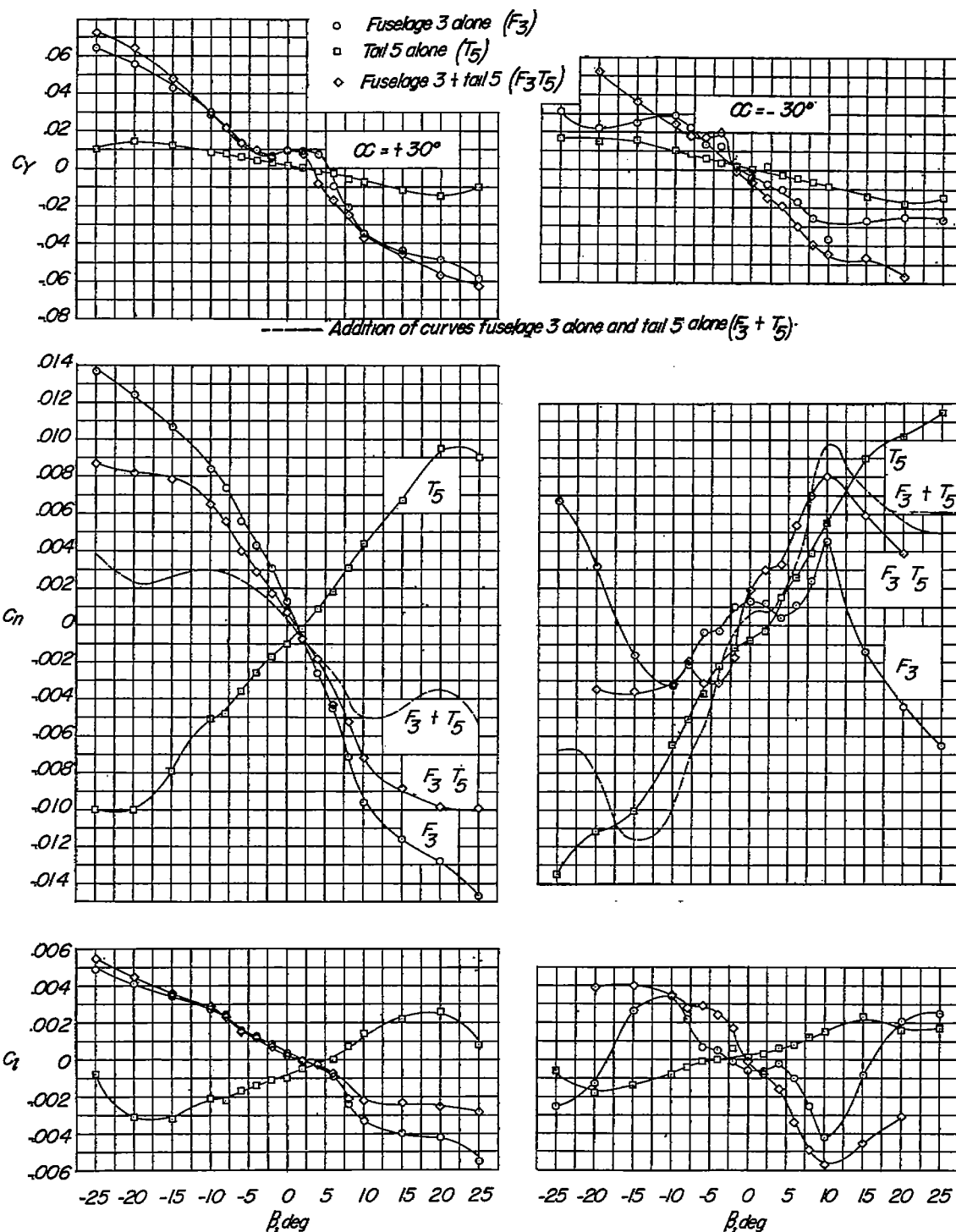
Figure 14.- Aerodynamic characteristics in sideslip of the nonoverlap-type fuselage and basic tail, showing the contribution of the fuselage alone and tail alone for angles of attack of 30° and -30°.
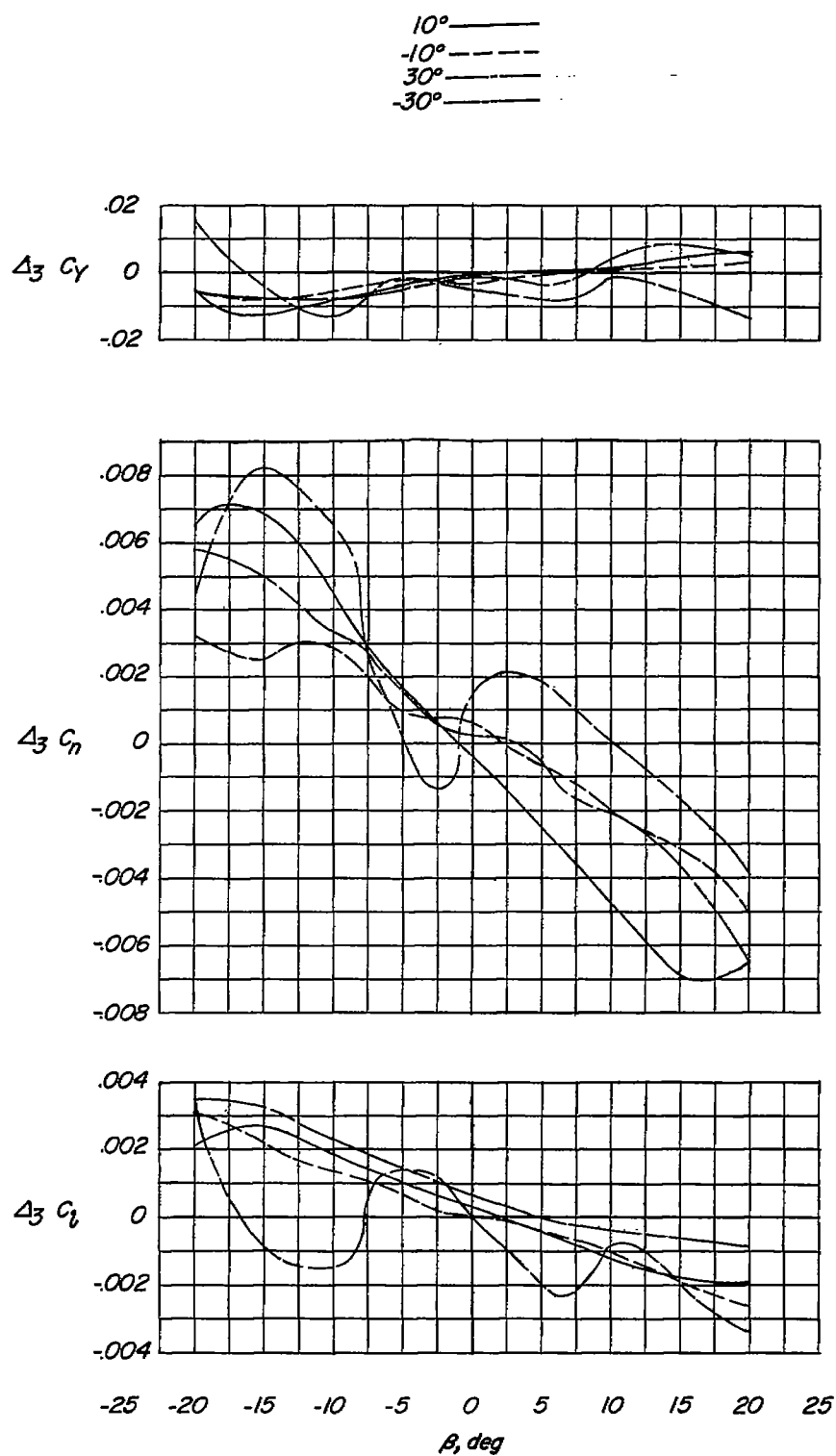
Figure 15.- Mutual interference in sideslip between the tail and fuselage for the nonoverlap-type fuselage at four angles of attack.

$\beta = -10°$

$\beta = 0°$

$\beta = 10°$

$a = 0°$ $a = 20°$

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Figure 16.- Tuft-grid pictures of the nonoverlap-type fuselage without
tails.   Screen is 6 inches behind model.   q = 8 lb/sq ft.

○ *Fuselage 4 (reference 10)*
□ *Non overlap fuselage alone*
◇ *Overlap fuselage alone*
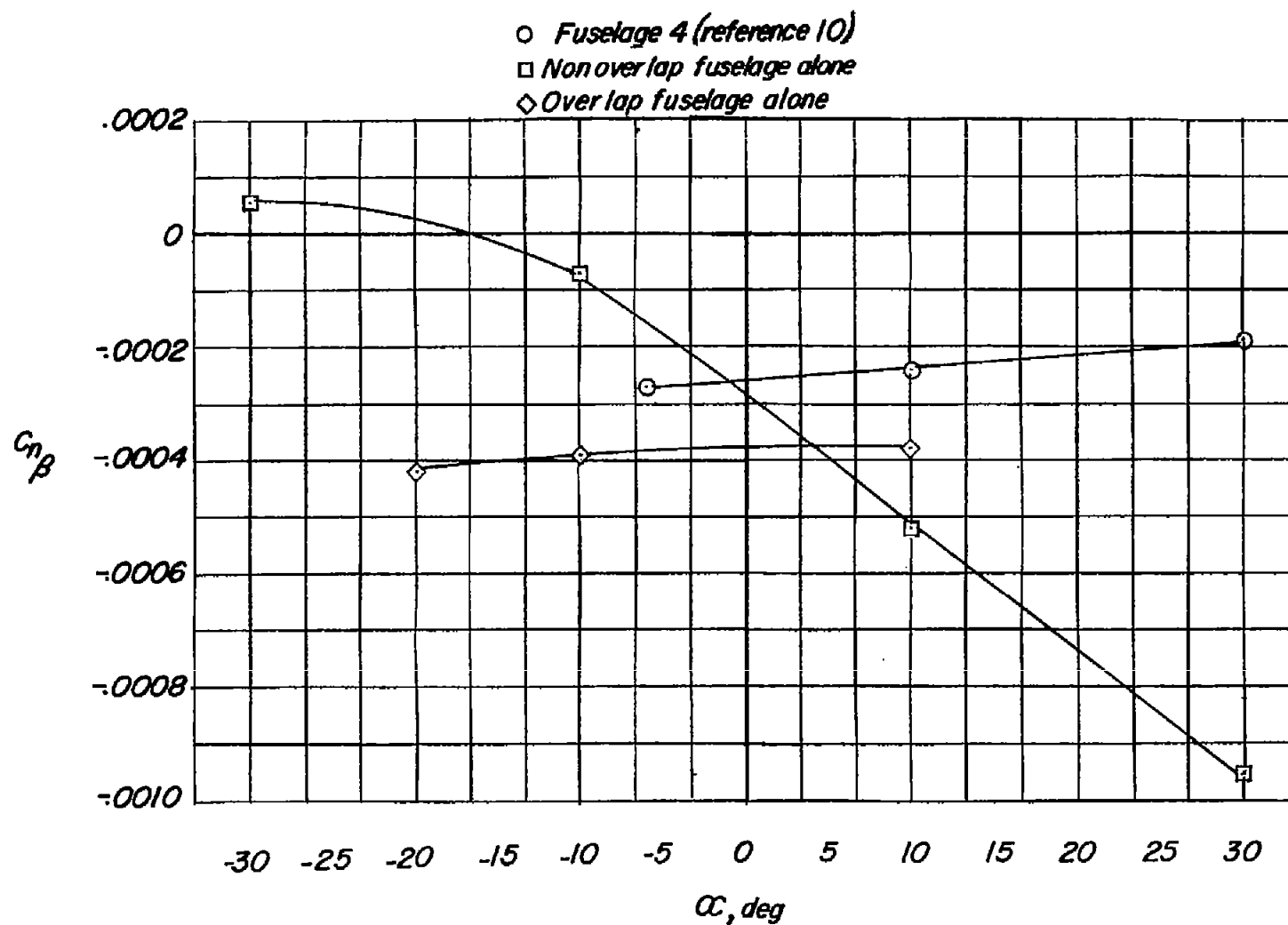
Figure 17.- Comparison of the variation of directional stability with angle of attack for the overlap- and nonoverlap-type fuselages and fuselage 4 of reference 10.

Figure 18.- Aerodynamic characteristics in sideslip of the nonoverlap-
type fuselage and basic tail showing the effect of spoilers for
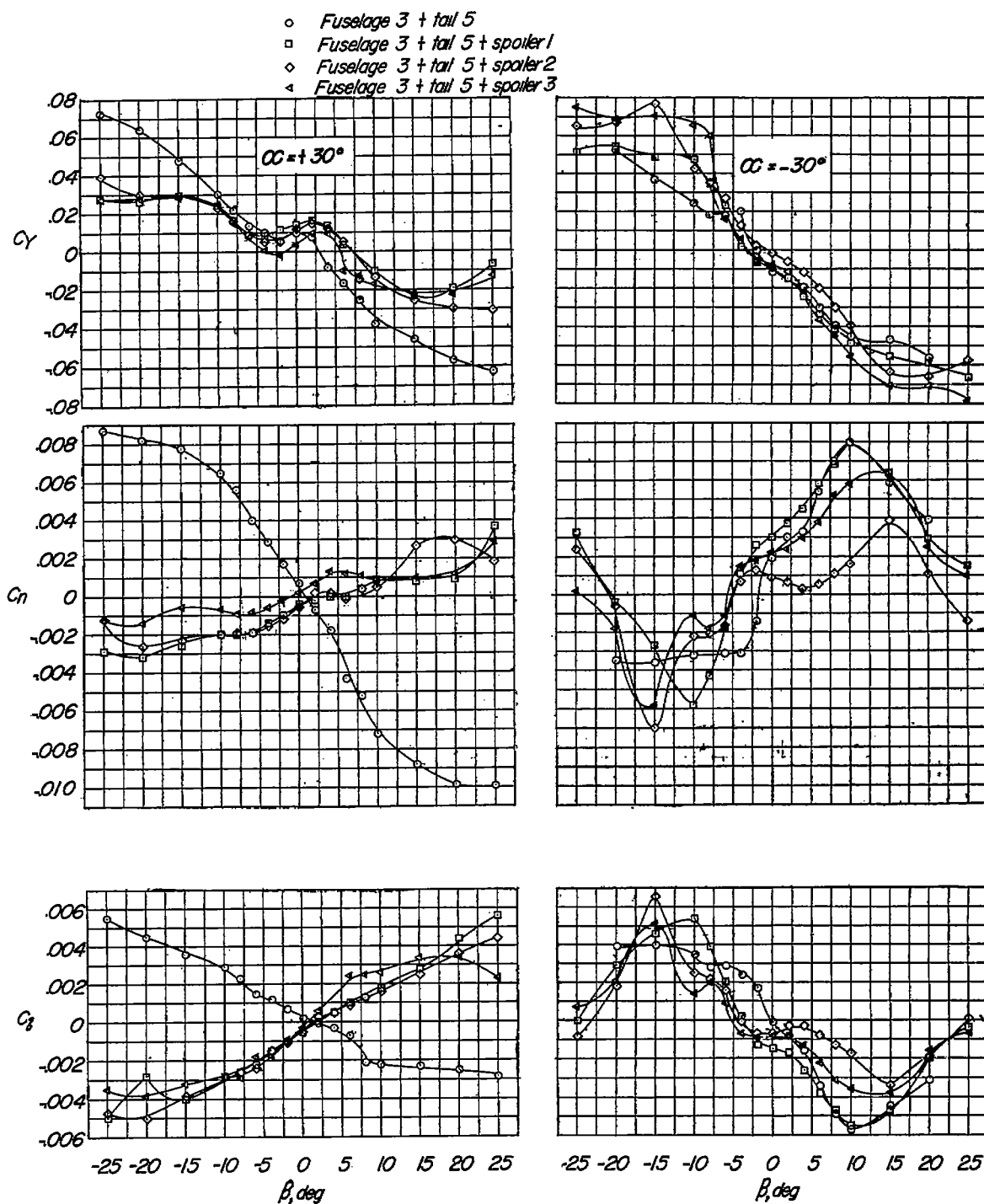angles of attack of 10° and -10°.

Figure 19.- Aerodynamic characteristics in sideslip of the nonoverlap-
type fuselage and basic tail showing the effect of spoilers for
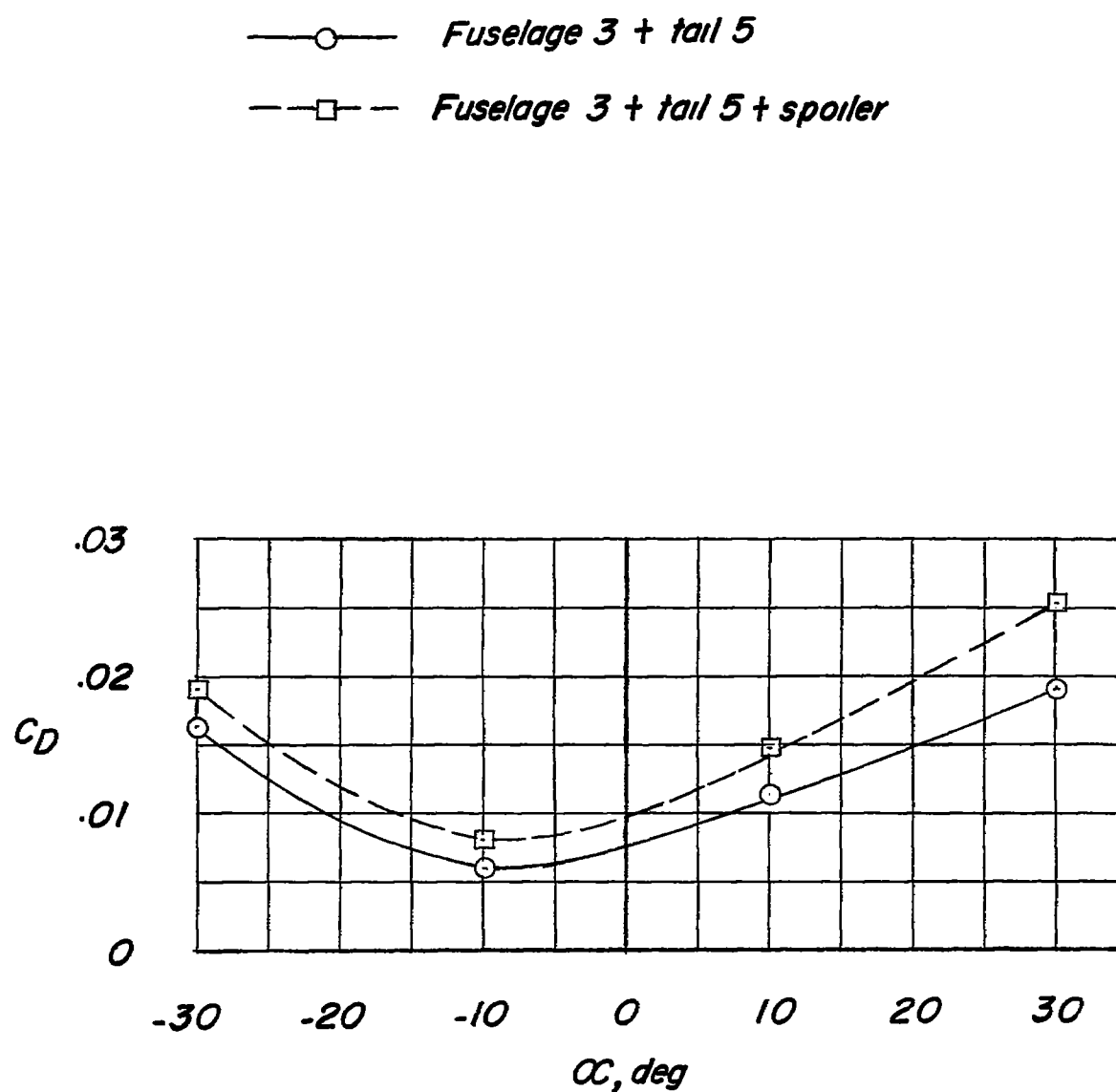angles of attack of 30° and -30°.

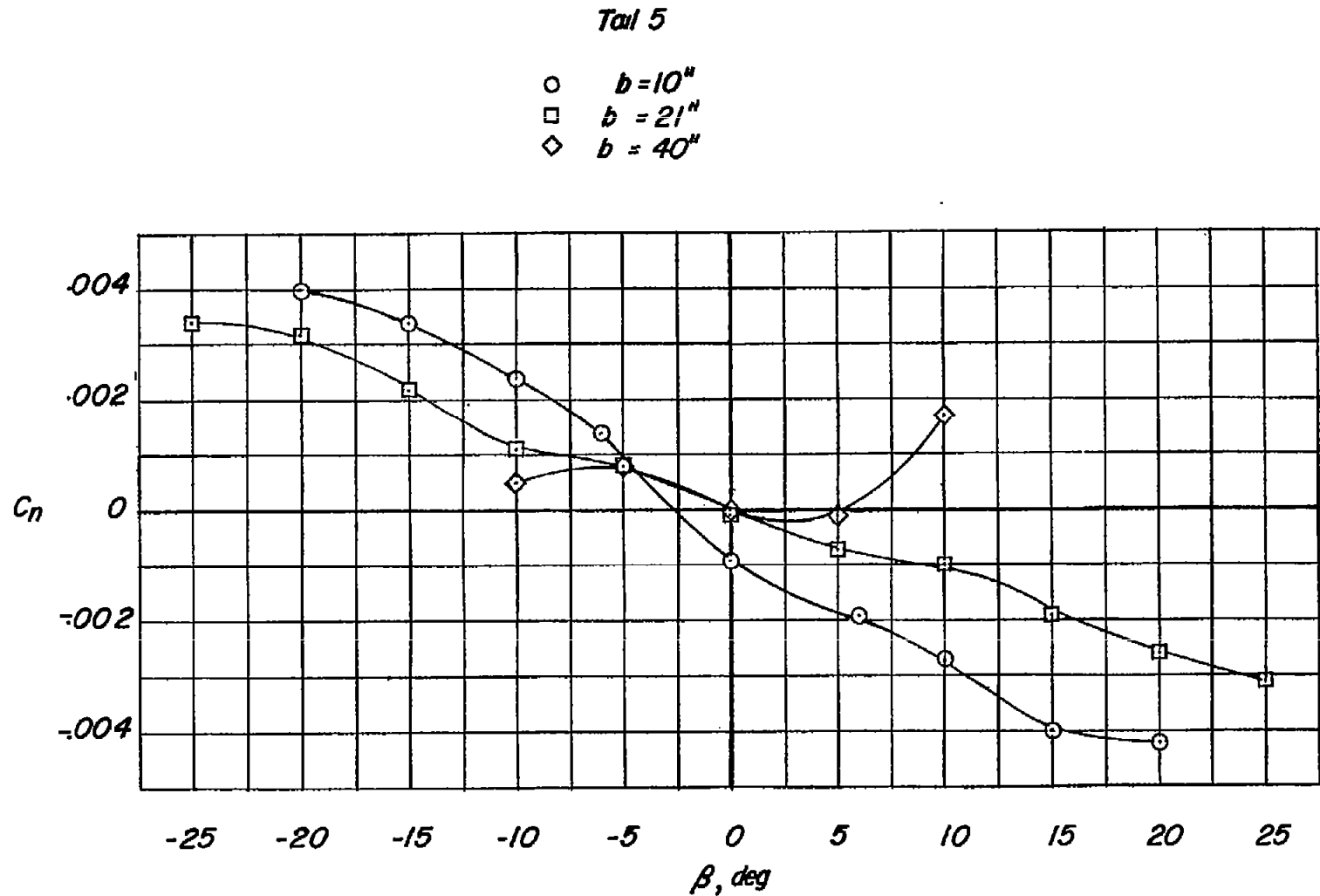Figure 20.- Effect on drag coefficient of adding spoiler 1 to nonoverlap-type fuselage with basic tail.

Tail 5

○ $b = 10''$
□ $b = 21''$
◇ $b = 40''$

C_n

β, deg

Figure 21.- Effect of location of vertical tail (A = 1.3) on yawing-
moment coefficient in sideslip of the nonoverlap-type fuselage
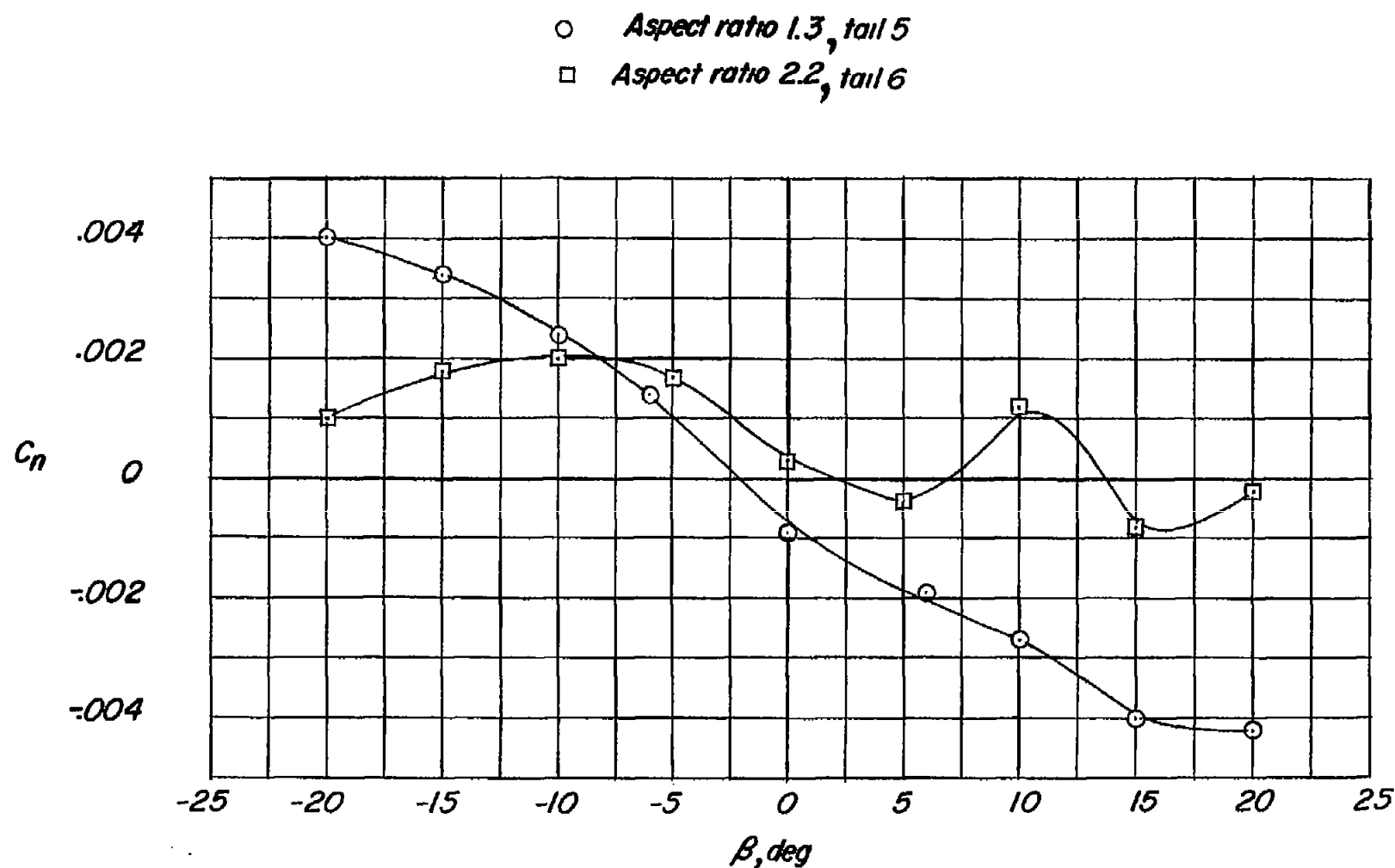model. $\alpha = 10^\circ$.

Figure 22.- Effect of vertical-tail aspect ratio on yawing-moment coefficient in sideslip of nonoverlap-type fuselage model. $\alpha = 10^{\circ}$; b = 10 inches.

Tail 6

○ $b = 10''$

□ $b = 21''$

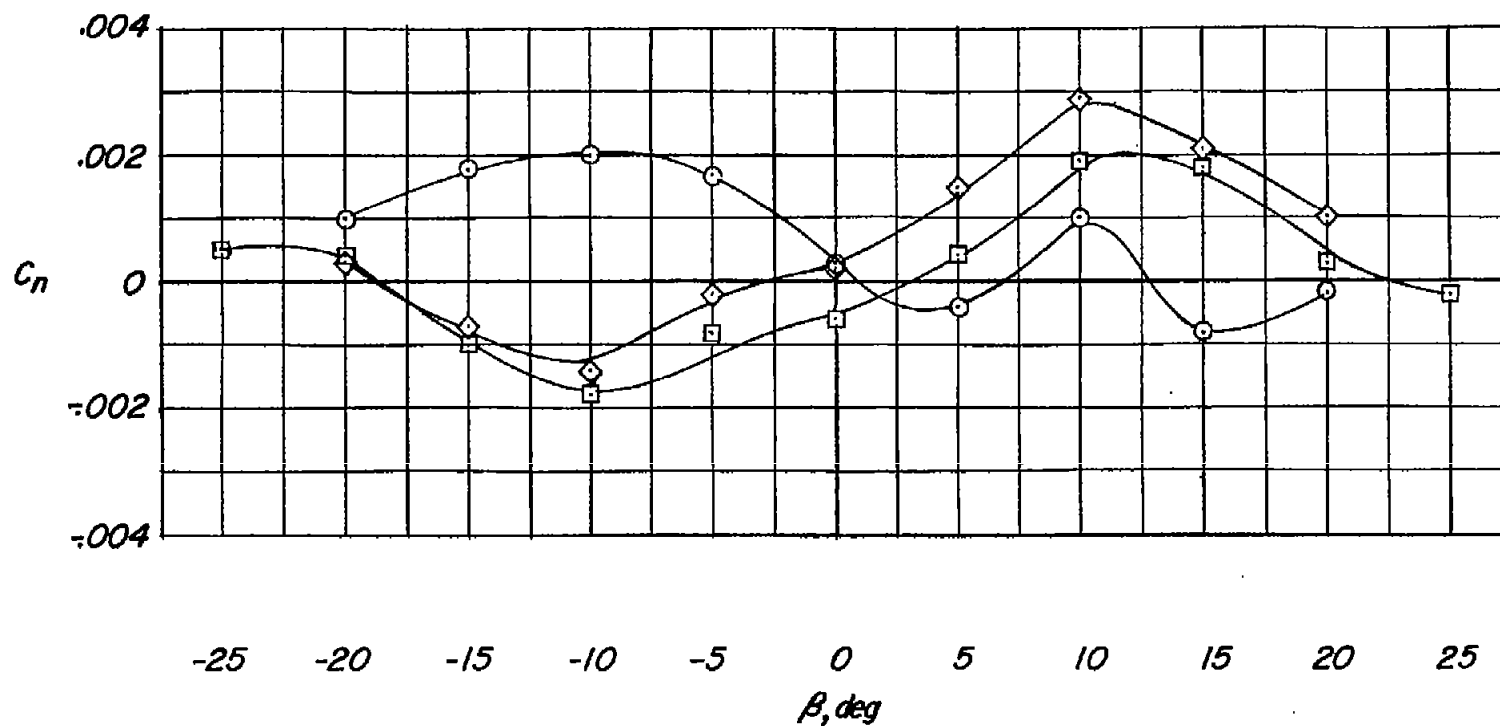◇ $b = 21''$ Tails lowered 14 per cent of horizontal tail span.

Figure 23.- Effect of location of vertical tail (A = 2.2) on yawing-moment coefficient in sideslip of the nonoverlap-type fuselage model. $\alpha = 10^{\circ}$.